DEBIPRASAD CHATTOPADHYAYA

HISTORY OF SCIENCE AND TECHNOLOGY IN ANCIENT INDIA

The Beginnings

With a Foreword by

JOSEPH NEEDHAM

FIRMA KLM PRIVATE LIMITED

"It is almost too much of an honour for me to be asked to contribute a foreword to this new book of Chattopadhyaya and the team of excellent scholars which he has gathered together to help him in the enterprise. When I was younger I thought I knew something about the history and philosophy of India, but now I realise how little it was. Yet it is quite clear that the history of science and technology in India will bear comparison with that of other ancient civilisations, and I would like to congratulate the main author and all his colleagues warmly on this endeavour, which they have brought to such a successful fruition... Here in this present book we have the beginning of the story, and most exciting it is..."

—Joseph Needham. (extract from the *Foreword* of the present book).

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Aid to the reader

1. *Notes and References*

The references in the foot-notes are to the works given in the Bibliography. Where only one book by an author is included in the Bibliography only his name occurs in the foot-note; where more than one work is included in the Bibliography by the same author, the name of the author is followed by the initials of the title of the work in Roman capitals. Contributions to journal-articles and general reference works are indicated by the word 'in' preceding these.

2. *On the Indian Words*

Diacritical marks for Indian words are avoided in the body of the book. But all Indian words occurring in the text are included in the Index with diacritical marks to indicate their phonetic value.

3. *Invited Contributions*

Invited contributions from the following are included in the book. *Articles* : D. P. Agrawal, Navjyoti Singh and Santanu & Sujata Maiti. *Appendices* : Apurba Kumar Chakrabarty, Navjyoti Singh, Ramatosh Sarkar and Subinoy Ray. *Brief Comments* : Dilip Kumar Chakrabarti and Partha Ghosh.

Foreword for Debiprasad Chattopadhyaya's "History of Science and Technology in Ancient India"

JOSEPH NEEDHAM

It is almost too much of an honour for me to be asked to contribute a foreword to this new book of Chattopadhyaya and the team of excellent scholars which he has gathered together to help him in the enterprise. When I was younger I thought I knew something about the history and the philosophies of India, but now I realise how little it ever was. Yet it is quite clear that the history of science and technology in India will bear comparison with that of all the other ancient civilisations, and I would like to congratulate the main author and all his colleagues warmly on this endeavour, which they have brought to such a successful fruition.

Debiprasad Chattopadhyaya made his name in the world of learning some thirty years ago, with his book "Lokayata" in which he showed how much theoretical materialism there had been in ancient India, and how it had been systematically obscured and vilified by the theologians of all the Indian religions. He has never ceased to uphold the banner of the naturalists of India, and some twenty years later, in his book on "Science and Society...." he showed in detail how the medical men had to struggle against the religious theorists. The former were searching for the naturalistic causes of disease—a point of view entirely justified by modern medical science—but the theologians always wanted to attribute diseases to the bad *karma* incurred in previous existences. All this could be demonstrated particularly by the nature and fate of the ancient medical book *Caraka-samhita*.

If there is one thing more than anything else which has characterised the work of Chattopadhyaya from the beginning, it has been his conviction of the importance of relating the history of science, technology and medicine to the social conditions which surrounded their growth. This principle will alone enable us to understand in depth the story of their slow development. For example, take the grand question which looms behind all the volumes of "Science and Civilisation in China", why, in spite of so many wonderful discoveries and

inventions during sixteen or seventeen centuries before the Scientific Revolution, did modern science not develop in China but only in Europe? The answer can only be stated in social and economic terms. Only when one knows that China was characterised by bureaucratic feudalism, while Europe had military-aristocratic feudalism, seemingly stronger but in fact much weaker, and so exposed to overthrow when the time came for the rise of the bourgeoisie; then only can one begin to see why modern science, along with capitalism and the Reformation, originated in Europe and in Europe alone. How things went in India I could not attempt to say, but I would expect that apart from wars and colonialism, some concrete social and economic factors will in the end account for the fact that, in spite of wonderful past achievements, modern science did not originate there either.

Here in this present book we have the beginning of the story, and most exciting it is. Chattopadhyaya and his colleagues speak of two urbanisations, the first associated with the Indus Valley culture which produced such splendid cities as Mohenjo-daro and Harappa—roughly speaking corresponding to the Shang-Yin civilisation of China or rather earlier, and the beginning of the 2nd. millennium BC. The reasons for their decline and fall are not yet fully understood, and the subject is discussed here, but it is sure that they were followed by the Aryan invasions and the Vedic Age. Then came the second urbanisation in the 6th century BC. Although the Indus Valley script is not yet fully interpreted, we can see from ocular aspection (as Sir Thomas Browne would have said) the wonders of their hydraulic engineering systems, and the great harbours that they built for their maritime commerce, presumably with the Middle East.

Perhaps the most illuminating correlation which this book contains—or so it was for me—is that the first beginnings of mathematical geometry in India, later preserved in the *Sulva-sutras*, was a direct result of the baked brick industry of the Indus Valley cities. This was rather earlier than either Rome or China, where we do not seem to find baked bricks much, before the Warring States period in the 1st. millennium BC. But in any case, the industry was a very early example of mass-production, and since sizes of all shapes had to be exactly specified, their geometrical relationships shown in building

would naturally follow. But throughout the book, for example in metallurgy and in ceramics, there is no lack of other examples of practice coming first, and then theory arising out of it afterwards.

Yet another interesting question taken up by Chattopadhyaya is to what extent there was genuine curiosity and nature-study among the Indus Valley people; in astronomy for example. Did they trace the path of the moon through the stars, and did they originate the *nakshatra* moon-stations, which we call *hsiu* in China? There has long been controversy about what civilisation it was that initiated them; perhaps this book will help to settle it.

Again, all that has been written here about *rta*, that ancient Indian concept of the Order of Nature, its pattern and organisation, self-originating and underlying all that happens, is well worth reading. This concept is somewhat analogous with what in Chinese we call the *Tao*, or *li*, also self-originating, *tzu-jan*. Apparently it was not characteristic of the Indus Valley civilisation but rather to be found in the *Rgveda* and such works. As a recognition of the regularity and uniformity of Nature it was certainly wisdom, but it had to be fleshed out with specific theories about natural phenomena, and these to a large extent arose out of technological practice. Of course it was the ancestor too of what today we call "laws of Nature", those laws which Westerners once thought of as due to the will of a transcendent creator deity, but which are now regarded as descriptive rather than prescriptive.

Finally I should like to say that I sympathise very much with the attempt to "de-mystify" ancient science, and to destroy the arguments which primitive theology brought against it. But we must beware of "pouring out the baby with the bath-water" (as we say in my country). Today ethics is needed more than ever, whatever one's attitude may be to developed religion. One of the most striking experiences of my life has been connected with the ethical value to be attached to science. When I was young, in the thirties of the present century, I was one of the "Science and Society" movement among the "younger scientists" of the time. It never occurred to any of us that science was something inimical to mankind, or dangerous; the whole complaint of colleagues like J. D. Bernal was that capitalism prevented the full employment of science for human benefit, and

that was quite reason enough for opposing it. But the whole situation has utterly changed since the Second World War. People in general are now suspicious and fearful of science, only too conscious of its dread possibilities—whether in atomic and chemical weapons, nuclear power, acid rain, environmental pollution, genetic engineering, loss of privacy due to information banks, etc. etc. The fact that so many of these things are due to the machinations of evil men, engaged in the struggle for wealth and power, is forgotten. Capitalism, the very incarnation of this struggle, still stands condemned. But now people are desperately afraid of what modern science and industry are capable of, as in the recent case at Bhopal. This has been one of the greatest changes which I have seen in my not too short life, and it seems to me that ethics and morality are more necessary than ever for the human condition.

But now it only remains to salute Debiprasad Chattopadhyaya's new book, and to wish every success to it and to the volumes which will follow it.

Cambridge
June 15, 1986

Joseph Needham

AUTHOR'S PREFACE

A study in science and technology in Indian history is much more than a matter of mere academic exercise. It has profound significance for our national requirements, specially in these grim days through which we are passing. We shall try to explain this, beginning with some accredited admissions.

In the inaugural address to the fiftyfifth session of the Indian Science Congress (Varanasi), our prime minister observed: "We must transform an ancient tradition-bound people into a modern nation." For this purpose, she naturally looked for aid from science: "The quicker way is that of science. What do we expect of science? The immediate answer is, generally, that we seek for more advanced technologies and their application to bring material benefit and to take knowledge and training within the reach of different sections of our people, thus enabling them to produce wealth in their fields and factories and to exploit our vast untapped resources. While this must remain a primary objective of scientific endeavour in any country, we are equally aware of the importance of other aspects and of basic science."

Hence she felt anxious to report on how much her government had already done for the spread of science in this country: "It is a measure of our resolve to give science and technology an important place in our scheme of things that India has made considerable investment in stimulating their growth. The awareness of science and technology is part of our national policy and we have made strenuous efforts to give practical shape and content to this ideology in the form of institutions. We have today some thirty national research laboratories. We have more than a dozen major agricultural and medical research centres. We have seventy universities and a sophisticated atomic energy programme."

Still, the prime minister felt that there was something wrong somewhere, and hence added: "And yet we must admit that all these developments have not made a significant impression on the consciousness even of our scientists, educationists and policy planners. We do still continue to lead a somewhat schizophrenic existence—one half of our individual self pays

homage to science and the scientific approach, while the other half remains deeply rooted in the past. Paradoxically enough, this applies even to some who work in science!" There was thus something that resisted the scientific approach, without overcoming which scientific education itself could not serve the purpose of developing the scientific outlook proper.

What, then, is this force of resistance?

This led the prime minister to re-examine the question of traditional thought. And she observed: "Much of what is called tradition in our country is no more than a fossilization of thought and habit. These layers of superstition and dead habit have no meaning in our times or relevance to our needs. They impede the growth of science and the scientific temper. This dichotomy between our social life and scientific needs has to be overcome. Our science should not only be an effort of individuals and institutions, but should develop general social significance and movement."

All this was said in 1968. In the meanwhile, the number of our universities has gone up, science laboratories and research centres have gained both in quantity and quality: these are now better financed and better equipped. Sophisticated research in various branches of science is increasingly gaining global prestige. How much, indeed, is being done for science and technology in India today!

But that is only one side of the picture.

Also happened in the country events that are absolutely stunning—assasinations, murders, caste malevolence and communal carnage. Factors operating behind all this are complex no doubt. What specially concern us here are those that may broadly be called ideological. How much of the scientific temper is actually cultivated among the people—a temper that has a good deal to do in changing their consciousness so that they can rise above the false lure of casteism, communalism and regional chauvinism? Not surely in a scale that can make us feel proud. Even the working scientists cannot absolve themselves of the responsibility of this failure; they cannot seek convenient evasion of their responsibility under the shelter of sophistication and specialisation.

Science is not a mere marvel, or better, that which makes

it really marvellous is the basic attitude that makes it possible. It is, in short, the scientific temper, of which the scientists themselves are expected to be the best custodians.

An antidote to the malevolence with which we are being confronted today is the spread of the scientific temper. And one of the special problems created in the country is the illusion fomented by the regional chauvinists, communalists and fundamentalists is their claim to be the real custodians of our national cultural heritage. The claim is a fiction—in fact the most dangerous fiction. And it has got to be debunked. But it cannot be debunked with mere demagogy. We have to lead our people to meet the technicians, engineers and scientists in our own history and to show how they were defending the scientific temper in their own way, defying the dark forces that threatened it. This had indeed been a very significant aspect of our national cultural heritage. We have also to try to lead our people to see what, in the past, inhibited our scientists—with all their personal gifts—to move forward to what is ordinarily called modern science, i.e. science in the sense that developed in Europe from the days of Galileo and others. When we do this, we are confronted with an unexpected situation. The factors that inhibited the development of modern science in Indian history are inclusive of those that are still creating the zeal for casteism and communalism, murder and malevolence. In other words, we meet the same monster from whom inspiration is still being drawn, often surreptitiously though also often overtly.

That is why, a study of science in Indian history is more than a mere academic exercise. It is linked up also with the question of our very survival. At least that is how we have tried to define our task. Not that we want to flatter ourselves with the idea that the task is successfully executed in our own study. We are aware of its limitations and shortcomings. Nevertheless, nothing would be more rewarding for our labour if our own limitations irritate better scholars to carry on the work with superior abilities and in sounder lines.

I am anxious here to add only one more point. Without the moral and material support received from the National Institute of Science Technology and Development Studies and also the untiring labour of my colleagues who worked with me,

I could not write this book, or at least could not have completed it within a rather brief period. However, the views expressed here are mine and so also are the errors. In any case, the views expressed are by no means to be considered as those of NISTADS.

Calcutta
May 24, 1985.

Debiprasad Chattopadhyaya

ACKNOWLEDGEMENTS

I am profoundly grateful to Professor A. Rahman, then Director NISTADS, for initiating the project on the history of science and technology in India and for giving me the responsibility of looking after the ancient period of the work. Every help that I required and asked for was readily given to me. Besides, his otherwise busy programme notwithstanding, he never hesitated to spare sufficient time to discuss with me certain academic questions on which I required clarification.

Professor A. Rahman retired from the post of the Director of the NISTADS when the work on this book was under progress. He was succeeded by Dr. Ashok Jain. I am happy to mention that in spite of this change in the administrative set-up, the moral and material help received for this work from NISTADS remained unaffected. Dr. Ashok Jain have been helping in all possible ways to work on the present history.

Besides A. Rahman and A. Jain I am most grateful to Dr. Sushil Kumar Mukherjee, to whose unpretentious and characteristic modest way of helping the present generation of our scientists is well-known. The active help and guidance I personally received from him has been most encouraging.

Sense of gratitude demands that I mention here the following. On a personal invitation of Dr. Joseph Needham—and with the financial support received from NISTADS and the British Council—I had recently the opportunity of spending some weeks at Cambridge. Dr. Needham spared long hours with me to discuss the general plan of the book and the methodology required for working on it. It has been exceedingly kind of him to contribute a *Foreword* to the book and this in spite of his present age and the incredible pressure of work of his own. I do not honestly know how to express my gratitude to him adequately.

The Cambridge visit also gave me the opportunity to discuss with Bridget and Raymond Allchin many questions concerning Indian archaeology, which proved most valuable for me.

As for the general understanding of ancient Indian history, I had never any hesitation to approach Professor R. S. Sharma, freely exploiting his personal affection for me.

Three chapters in the book and the *Appendices* are contributed by other scholars, whose names are mentioned in proper places, though I must add that I was truly surprised by the readiness with which a scientist of the stature of D. P. Agrawal agreed to associate himself with my humble work.

I am anxious to mention here the names of two other scientists—Partha Ghosh, the physicist, and D.K. Chakrabarti, the archaeologist. The former made a critical assessment of the recent claim of some (advertised in a rather big way) that the modern theory of unified field is already to be found in the Vedas. His assessment of the claim is to be found in pp. 400-402 of the present book. D.K. Chakrabarti recently told me in Delhi that he was preparing a paper on the agricultural technology in the Harappan period. Since he evidently needs a longish time to complete the paper, he readily agreed to my request to prepare a synopsis of his main points which is to be found in pp. 110-11 of the present book.

Talking of archaeology I must mention here the long discussions I had the opportunity to have with N. C. Ghosh (now of the Visvabharati University) which proved very useful for my own clarifications.

As for the young colleagues on whom I have throughout depended I am anxious to mention here specially the following : Santanu Maity, Subinoy Kumar Ray, Sujata Maity, Ramkrishna Bhattacharyya, G. Ramakrishna, Sanjay Biswas and Ramakrishna Maitra.

I am thankful to Hrishikesh Chakraborty for typing (and often retyping) the entire manuscript.

Debiprasad Chattopadhyaya

BACKGROUND NOTE

ASHOK JAIN

Director NISTADS

Influences of science and technology, some pleasant and some not so pleasant, are seen in the shades and textures of different social fabrics. One of the central areas of enquiry of the National Institute of Science Technology & Development Studies (NISTADS) has been to understand the nexus between science, technology and society. In this context, it was felt that an elucidation of the relationship between science and society in different periods of Indian history was essential. We were conscious of the fact that when the professional historians of India were still debating on many questions concerning the economic, political and social history of the country, it would be premature to attempt any final version of the history of scientific and technological activities in India. What was nevertheless possible—and considered necessary—was to try to make some probe into it, howsoever tentative and sometimes even controversial may be the result reached by it.

This was the guiding idea of Professor Nurul Hasan, then the Vice-President of the Council of Scientific & Industrial Research (of which NISTADS is a constituent establishment) when he desired initiation of a project on the History of Science & Technology in India. Professor A. Rahman who was then the Director of NISTADS set up three teams in Calcutta, Lucknow and NISTADS to work on the project to cover the ancient, medieval & modern periods respectively.

Professor Debiprasad Chattopadhyaya in Calcutta kindly agreed to guide the work covering the ancient period and set up a team for it. The present book embodies the results reached by this team for the pre-historic and proto-historic periods.

It needs to be specially emphasised that the present elucidation, tentative as it may be, reflects the understanding and viewpoint of the scholar entrusted with the work. Professor Debiprasad Chattopadhyaya requests me (true to the spirit of scholarship) to state very clearly and categorically that the

views expressed by him in this book are his own and he takes full responsibility of the authenticity of the materials on the basis of which he has attempted to reach here certain results. Nevertheless, I would like to add that though NISTADS as an institution has not formulated views on the subject or arrived at conclusions, we are happy that our support had enabled Chattopadhyaya to initiate a probe into the history of science and technology in ancient India. This book, we feel, is a good beginning. Amendments, corrections and elaborations may be required in the future ; even the controversies it may provoke are likely to stimulate a deeper probing into the subject by other scholars. As Professor Debiprasad Chattopadhyaya unhesitatingly acknowledges his indebtendness to his predecessors—inclusive of those with whom he sometimes sharply differs—so also the future scholars may positively or negatively be indebted to him. But then if the book generates scholarly interest in the history of science and technology in ancient India, NISTADS would have justified its role.

New Delhi *Ashok Jain*
September 12, 1986.

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(Contributed by Navjyoti Singh)

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CHAPTER I

INTRODUCTORY

In science, more than in any other human institution, it is necessary to search out the past in order to understand the present and to control the future.

Such an assertion would, at least until recently, have received scant support from working scientists. In natural science, and especially in the physical sciences, the idea is firmly held that current knowledge takes the place of and supersedes all the knowledge of the past. It is admitted that future knowledge will in turn make present knowledge obsolete, but for the moment it is the best available knowledge. All useful earlier knowledge is absorbed in that of the present; what has been left out are only the mistakes of ignorance. Briefly, in the words of Henry Ford, 'History is bunk.'

Fortunately more and more scientists in our time are beginning to see the consequences of this attitude of neglect of history, and with it, necessarily, of any intelligent appreciation of the place of science in society. It is only this knowledge that can prevent the scientists, for all the prestige they enjoy, being blind and helpless pawns in the great contemporary drama of the use and misuse of science. It is true that in the recent past scientists and people at large got on very nicely in the comfortable belief that the application of science led automatically to a steady improvement in human welfare. The idea is not a very old one. It was a revolutionary and dangerous speculation in the days of Roger Bacon and was first confidently asserted by Francis Bacon 300 years later. It was only the immense and progressive changes in science and manufacture that came about with the Industrial Revolution that were to make this idea of progress an assured and lasting truth—almost a platitude—in Victorian times. It is certainly not so now, in these grim anxious days, when the power that science can give is seen to be more immediately capable of wiping out civilization and even life itself from the planet than of assuring an uninterrupted progress in the arts of peace. Though even here doubt has crept in and some neo-Malthusians fear that even curing disease is dangerous on an overcrowded planet.

Whether for good or ill the importance of science today needs no emphasizing, but it does, just because of that importance, need understanding. Science is the means by which the whole of our civilization is rapidly being transformed. And science is growing; not, as in the past, steadily and imperceptibly, but rapidly, by leaps and bounds, for all to see. The fabric of our civilization has already changed enormously in our own lifetimes and is

> changing more and more rapidly from year to year. To understand how this is taking place it is not sufficient to know what science is doing now. It is also essential to be aware of how it came to be what it is, how it has responded in the past to the successive forms of society, and how in its turn it has served to mould them.
>
> —J. D. Bernal, *Science in History*

1. PRELIMINARY REMARKS

We have quoted J. D. Bernal not because we have the intention—and certainly not the ability—to treat the question of science in history in the vast global canvas which he so inspiringly does. Our own scope is, in comparison, extremely limited. Nevertheless, it is necessary for our purpose to have a valid general perspective and also an acceptable methodology for the work. What we have quoted from Bernal provides us with both—better than many other works on the subject we are aware of. But this does not mean that all of our own scientists were totally unaware of the need of basically the same perspective and the same methodology, howsoever different might have been their modes of expression and how much fundamentally different might have been the general intellectual climate and socio-economic conditions in which they worked. We have chosen to illustrate this specially with two of the makers of modern science in India—P. C. Ray and M. N. Saha—whose credentials as scientists it would be too churlish to question though whose approach to science in Indian history is not sufficiently emphasised by most of our writers on the history of science in India.

2. P. C. RAY

We shall begin with a few words on *acarya* Prafulla Chandra Ray (1861-1944), whose name became somewhat lagendary even during his lifetime. Of the manifold activities with which he was connected we have the scope here to mention only those that have immediate bearing on our present attempt to sketch the outlines of the history of science and technology in ancient India.

P. C. Ray was the first *notable working scientist* in India to have realised the importance of an intelligent appreciation of the place of science and scientific activities in Indian history.

It is true that his *History of Hindu Chemistry* (first published : vol. i, 1902/03 ; vol ii. 1908) was inspired to a considerable extent by the writings of M. Berthelot (1827-1909), about which Ray himself drew our attention in his *Autobiography*.[1] However, what specially interest us in the present context are some of the points on which Ray's *History* differs from that of Berthelot.

Berthelot, who succeeded Louis Pasteur as Secretary of the *Academie des Sciences*, Paris, belonged to an intellectual climate in which science as an intrinsic value was on the whole generally accepted. These were the days of great optimism about science in Europe. There was thus no need for any general defence of science and of the methodology of science, specially against the alleged claim of real knowledge to be found only in scriptural revelation. However, the intellectual climate to which Ray belonged was different. The defence of science—of the importance of observation and experiment on which it is based—was still frowned upon.

Among his predecessors Akshay Kumar Datta (1820-1886)—literally some kind of science-intoxicated man about whom much more requires to be written in our times[2]—was virtually ostracised and sacked from his job because of uncompromising enthusiasm for modern science and its implications. It may be incidentally mentioned here that, towards the end of his life, Datta himself was seeking the roots of science and scientific temper in the Indian history, so that it is not easily denounced as alien to our tradition, though this work was left unfinished by his illness and untimely death. Among the successors of P. C. Ray, the outstanding scientist Megh Nad Saha had to waste much of his valuable time for arguing against the orthodox champions of Indian spiritualism claiming that the wisdom of our ancient sages was inclusive of everything worthwhile in modern science, and hence the defence and cultivation of

1. P. C. Ray, *Auto* 93ff. The second volume of his *History of Hindu Chemistry*, first published in 1908, was dedicated to the memory of Berthelot.
2. A brief but very able summary of his life and struggle for the introduction of modern science in India is to be found in *Rationalist Annual*, 1962. pp. 20-30 *Akshay Dutt, Pioneer of Indian Rationalism* by A. K. Bhattacharyya.

modern science in India is nothing more than an index to our slavish mentality.[3] We shall have to see if, in spite of Saha's brilliant essays, the tendency continues in our times.

It was in such an intellectual climate that P. C. Ray had to work. Evidently, at least one factor that made him the first important working scientist in India to have worked on the history of science in India was to show that the tradition of science and scientific activity did form an important dimension of our national heritage. This made him, moreover, the first to realise the need for this purpose to be clear about the methodology of science. What was no less remarkable about him is that he drew our attention to the fact that the defence of this methodology was a matter of active struggle—a struggle not merely theoretical but also against the prevailing social conditions.

3. RAY'S PLACE AMONG THE PIONEERS

Others before P. C. Ray made no doubt the most wonderful pioneering work in rediscovering scientific aspects of Indian cultural heritage, though for this purpose they had to go against the stream—against the assumption generally prevailing among the European historians of science that science is an essentially European phenomenon. Leaving for the time being the discussion of this, and leaving also the account of the earlier visiting scientists like I-Tsing (643-713) and more particularly al-Biruni (973-1048), we cannot but recall here the names of a number of outstanding European scholars, without whose pioneering work our knowledge of science in Indian history would not perhaps have been what it is today. To mention only a few of them : H. T. Colebrooke (1765-1837), Alexander Csoma de Koros (1784-1842), A. Weber (1825-1901), E. Burgess (1805-1807), A.F.R. Hoernle (1841-1918), P. Cordier (1870-1914), F.G.W. Thibaut (1848-1914), J. Jolly (1848-1932), Th. Stcherbatsky (1866-1942),—to which many more names may indeed be added, though it is our misfortune that the Indian pandits under whom they learned the language and studied

3. We shall see how a scientist like M. N. Saha had to fight against this tendency, which unfortunately still persists.

their subjects are, generally speaking, not known to us.[4] But the fact remains that they did invaluable work in collecting the manuscripts, settling their reading and interpreting their science-potentials—works judged in the standard of sheer textual study have often been simply stupenduous. Specially for knowing the contributions to mathematics, astronomy and medicine in ancient India, contemporary investigators are often obliged to depend on them.[5]

But howsoever important their contributions might have been, the fact remains that they were antiquarians after all. Professionally speaking, most of them had little to do with natural science.[6]

It is thus one of the significant points on which P. C. Ray differed from most of them. He was above all a working scientist—in fact one that earned considerable reputation as a chemist even in Europe, having been elected a Vice-President in 1887-88 session of Edinburgh University Chemical Society, where, in the absence of the President-elect, he was required to preside over the session.[7]

Indeed, many aspects of his activities in introducing modern science to India are rather well-known. Under the most adverse circumstances and against the resistance of the colonial policy of the British rule, he succeeded in setting up the first full-fledged chemical laboratory in Calcutta in the University College of Science.[8] Among his "brilliant students" he mentions Jnan Chandra Ghosh, Jnanendra Nath Mukherjee, Makhanlal Dey. Satyendra Nath Bose, Pulin Behari Sarkar, Rasik Lal Datta, Nilratan Dhar and Megh Nad Saha.[9] Realising the importance

4. Little work is so far done on this, though undoubtedly it is in need of more intensive investigation.
5. For a selection of such pioneering works see, D. Chattopadhyaya (ed.) SHSI.
6. There were few exceptions to this : P. Cordier, and Buchanan-Hamilton e.g., were physicians by profession.
7. P. C. Ray, *Auto.* 56.
8. *Ibid* Chap. XV.
9. For the Bengalee readers, the most notable name in this connection is that of Rajsekhar Bose (See, Ray *Auto.* 404-5 and 89), who is better remembered as by far the most prominent writer of wit and humour in Bengali literature ; his lifelong devotion to build up the Bengal Chemical and Pharmaceutical Works Limited, is not generally remembered.

of science being actually applied to industry, he worked for building up the first Indian chemical industry, starting with the savings of his personal paltry salary, which, thanks to the support he received from some of his close Indian friends, eventually flourished as the Bengal Chemical and Pharmaceutical Works Limited.

Among the varied activities of this multi-dimensional personality what we want here to focus on, however, is one point. We are not aware of any other working scientist—none surely of the stature of P. C. Ray—to have developed an absorbing interest in science and scientific activities in Indian history. Understandably, much of this enthusiasm to seek roots of science in the Indian tradition was inspired by the spirit of national awakening of his time. As he himself says in the preface to the second volume of the *History of Hindu Chemistry*, "The Hindu nation with its glorious past and vast latent potentialities may yet look forward to a still more glorious future, and if the perusal of these pages will have the effect of stimulating my countrymen to strive for regaining their own position in the intellectual hierarchy of nations, I shall not have laboured in vain."[10]

We are aware, of course, of much more passionate expressions of the patriotic sentiment in those days, as we have also learnt the rather unfortunate results of the use of the word "Hindu" for Indians, as was somewhat customary in P. C. Ray's time.[11] But all this is besides the point of our present discussion. The point rather is that when a working scientist of P. C. Ray's stature wants to look back at the scientific activities in ancient and medieval India, the understanding of science itself acquires a dimension far more serious than that of mere antiquarian curiosity, as was more or less the case with Colebrooke and others. Thus while most of the other scholars were on the whole contributing to the preparation of some kind of inventory of the achievements of the ancient Indians in different departments of science, P. C. Ray raised and tried to answer questions far more important for our

10. P. C. Ray, HHC. Vol. 2, Pref. p.D.
11. That Ray himself was furthest from any communal understanding of the word "Hindu" will be seen from section 12 of the present introduction.

understanding of the history of science. We shall discuss mainly two of these. First, what it was that infused real vitality to the scientific activities in ancient India. Secondly, what it was that inhibited their growth and eventual decline.

4. RAY AND THE SCIENTIFIC TEMPER

The two questions are inter-related, and it remains for us to see how in answering these—specially the second one—P. C. Ray was in a sense ahead of his own times.

But let us begin with some of his general observations. In a lecture delivered in 1918, Ray observed :

I shall endeavour to unfold before you to-day a forgotten chapter in the history of the intellectual development of the Indian people, namely the cultivation of the Experimental Sciences. It is generally taken for granted that the Hindus were a dreamy, mystical people given to metaphysical speculation and spiritual contemplation. Due credit is, no doubt, assigned to them for the production of such priceless treasures as the Upanishads, the Six Systems of Philosophy, including the abstruse Samkhya and the Gita, with their transcendental teachings. But the fact that the Hindus had very large hand in the cultivation of the experimental sciences is hardly known in these days.

It should, however, be borne in mind that Experimental Sciences such as we now understand them are of very recent origin and growth, even in Europe.

The controversies of the Schoolmen in the Middle Ages lend colour to the theory that in approaching the discussion of the most evident truths of nature the learned men of Europe always avoided the test of appealing to experiments. As some of you are aware, a solemn discussion arose among the foundation members of the Royal Society as to whether a dead fish weighed more than a live one, though it never occurred to them that the solution of the problems lay in directly weighing a fish—live and dead. When the Royal Society was founded in 1662 by Boyle, Hooke, Christopher Wren and other students of Nature, Hobbes sneered at them as 'experimentarians.' If such was the respect for accurate knowledge even in England in the 17th century, we should not be justified in applying a rigid test to the knowledge of India in the past ages.

Experiments and observations constitute the fundamental bases of Sciences. It is naturally a relief to come across such dicta as laid down by two standard works on Hindu Chemistry, namely, *Rasendra-cintamani* by Ramacandra and *Rasa-prakasa-sudhakara* by Yasodhara, both belonging to the 13th or 14th century A.D.

Says the former : 'That which I have heard of learned men and have read in the Sastra-s but have not been able to verify by experiment

I have discarded. On the other hand those operations which I have, according to the directions of my sage teachers, been able to perform with my own hands—those alone I am committing to writing.

'Those are to be regarded as real teachers who can verify by experiments what they teach—those are to be regarded as laudable disciples who can perform what they have learned—teachers and pupils, other than these are mere actors on the stage.'

Yasodhara, the author of the latter, observes: 'All the chemical operations described in my book have been performed with my own hands—I am not writing from mere hearsay. Everything related is based upon my own conviction and observations'.[12]

In the modern writings on science in India, we have here for the first time a clear emphasis on the methodology of science—specially on the importance of observation and experiment—as of decisive importance for the making of science This emphasis on direct observation and experiment, went strongly against the dominant philosophical view in India and also against favourite priestly dictum that evidently sensed danger in science and the scientific method—in the attempt to know nature as it is without any alien addition. This must have been one of the factors that went against the emphasis on the need of interrogating nature by direct observation and experiment from which scientific activity drew its nourishment. P. C. Ray had the hindsight to note it. In his *History of Hindu Chemistry,* he found it necessary to have a special chapter on "Knowledge of Technical Arts and Decline of Scientific Spirit"—a theme which none before Ray felt the need of discussion, and which, among his notable scientist-successors only M. N. Saha cared to consider seriously. Though brief, there is much for the historians of science in India to draw from this chapter of P. C. Ray.

5. REJECTION OF THE INTERNALIST HYPOTHESIS

The first point to be noted about his discussion is that he wanted to see the real cause of the decline of the scientific spirit in India *not within* the general framework of science itself but *outside* it, i.e. mainly in the social conditions that developed in this country. This means, without being aware of the recent controversies over the hypothesis of the "inter-

12. P. C. Ray, in SHSI Vol. I, 344-5.

nalists" or "autonomists"—the hypothesis wanting to explain the history of science "solely in terms of the internal or autonomous filiation of ideas, theories, mental or mathematical techniques and practical discoveries, handed on like torches from one man to another", P. C. Ray did in fact reject it in his own way. The main cause of the decline of the scientific spirit in India was the entrenchment of caste society, with its disastrous degradation of the social status of the technicians, craftsmen and other manual workers. This, he thought, took place "when the Brahmins reasserted their supremacy on the decline and expulsion of Buddhism", because people in "the Vedic age did not form an exclusive caste of their own but followed different professions according to their convenience or natural taste."[13] How much the contemporary historians of India have to amend such a view of the triumph of the caste-society is evidently a different question.[14] Our point rather is, how much they have to learn from Ray's analysis of the effect of the caste-structure of society on the progress and development of science in India. As he put it :[15]

> The drift of Manu and of the later Puranas is in the direction of glorifying the priestly class, which set up most arrogant and outrageous pretensions. According to Susruta, the dissection of dead bodies is a *sine qua non* to the student of surgery and this high authority lays particular stress on knowledge gained from experiment and observation. But Manu would have none of it. The very touch of a corpse, according to Manu, is enough to bring contamination to the sacred person of Brahmin. Thus we find that shortly after the time of Vagbhata, the handling of a lancet was discouraged and Anatomy and Surgery fell into disuse and became to all intents and purposes lost

13. P. C. Ray HHC Vol. I, 192. A Vedic scholar would perhaps want to add that this was true only of the early Rigvedic period.
14. The literature on the origin of the caste system in India is already enormous and this is still being added to. Some idea of it may be obtained from Suvira Jaiswal in IHR Vol. VI, No. 1-2, pp. 1-63. It may however be mentioned in this connection that the contempt for manual work characterizing the caste system was unknown to the early Vedic Poets. See D. Chattopadhyaya, WLWDIP, 144 ff. It is generally believed that in the Rigveda the concept of the four castes is first foreshadowed in a very late hymn called the *Purusa-sukta*.
15. P. C. Ray HHC Vol. I, 192-197.

sciences to the Hindus. It was considered equally undignified to sweat away at the forge like a Cyclops. Hence the cultivation of the *Kalas* by the more refined classes of the society of which we get such vivid pictures in the ancient Sanskrit literature has survived only in traditions since a very long time past.

The arts being thus relegated to the low castes and the professions made hereditary, a certain degree of fineness, delicacy and deftness in manipulation was no doubt secured but this was done at a terrible cost. The intellectual portion of the community being thus withdrawn from active participation in the arts, the how and why of phenomena—the coordination of cause and effect—were lost sight of—the spirit of enquiry gradually died out among a nation naturally prone to speculation and metaphysical subtleties and India for once bade adieu to experimental and inductive sciences. Her soil was rendered morally unfit for the birth of a Boyle, a Des Cartes or a Newton and her very name was all but expunged from the map of the scientific world.

In this land of intellectual torpor and stagnation the artizan classes, left very much to themselves and guided solely by their mother wit and sound commonsense, which is their only heritage in this world, have kept up the old traditions. In their own way they display marvellous skill in damescening, making ornamental designs on metals, carving on ivory, enamelling, weaving, dyeing, lace-making, goldsmith's and jeweller's works, etc.

There was nothing new, of course, about censoring the evils of the caste-system. Many of our social reformers—inclusive of some of the contemporaries of P. C. Ray—did it, some perhaps with greater passion and eloquence than Ray showed. What was nevertheless striking about P. C. Ray is that he saw in the caste structure of society something that made science a prey to creeping paralysis. In contemporary terminology, the caste society ushered in and entrenched the ruinous separation of theory from practice—of mental work from manual work—as a consequence of the condemnation and degredation of actual craftsmen and technicians. But they alone possessed the tools and apparatus of interrogating nature, without which the "how and why" of phenomena cannot be known. The craftsmen and technicians were thus left only with their craftlores, improving these to the best of their abilities, but without enabling science proper to draw upon these and get enriched.

Since P. C. Ray was the first historian of Indian science to have clearly realised this point and to have boldly asserted it, we may as well try to understand some of its implications.

6. ON HEAD AND HAND

First, if the real clue to the decline of science is to be sought in the social degradation of the craftsmen and the technicians, it obviously follows that science draws its ultimate nourishment from the techniques. This does not mean, of course, that science is to be equated to mere technology. What it means nevertheless is that science is implicit in the techniques and hence inconceivable without the latter. It may be noted that P. C. Ray realised it already in the first decade of our century, i.e. long before the publication of E. Zilsel's famous paper on *The Genesis of the Concept of Physical Law*[16] which appeared in 1942, of B. Farrington's *Greek Science,* first published in 1944 and J. D. Bernal's *Science in History* which was first published in 1954—works that have given a new turn to the historiography of science and in which basically the same theme is worked out, though understandably with more historical data.

Farrington's *Greek Science* and also his subsequent brief but brilliant book *Head and Hand in Ancient Greece,* first published in 1947, lead us to see the second significant point sought to be emphasised by P. C. Ray. Though we do not expect of Ray the wide range of Greek studies as that of Farrington, it would be wrong to overlook the fact that Ray wanted to understand in his own way that this calamitous consequence for science resulting from the degradation of manual work was some kind of universal phenomenon, as was evident *also by what happened in ancient Greece.* Farrington himself emphasises this point as a correction to the lop-sided importance often attached to purely theoretical accomplishments of the ancient Greeks usually alleged to account for their scientific achievements. "Many moderns", says he, "misled no doubt by some of the ancient Greeks themselves, have combined pride in the theoretical brilliance of Greek science with a wish to ignore or deny its practical triumphs."[17] Among other things what such a tendency fails to take note of is the adverse effect on Greek science of Aristotle's attempted justification of slavery,

16. This paper forms a landmark in the contemporary approach to the history of science from the social point of view. We shall see more of it later.
17. B. Farrington, GS 18.

notwithstanding the personal genius of Aristotle himself. We have a brilliant analysis of this in Farrington's *Greek Science*.[18] What appears to be remarkable about P. C. Ray is that decades before the appearance of Farrington's work and depending only on comparatively meagre information about the Greek situation available to him, he wanted to draw our attention to basically the same phenomenon as illustrating the ruinous consequence for science resulting from the contempt and social degradation of the manual workers, as it happened in India. Thus he observed :

Similar dangers have threatened Europe from time to time but her sturdy sons have proved better of them in the long run. Thus 'Aristotle's opinion that industrial work tends to lower the standard of thought was certainly of influence here. In accordance with this dictum the educated Greeks held aloof from the observation and practice of technical chemical processes ; a theoretical explanation of the reactions involved in these lay outside their circle of interest.

Paracelsus flings a sneer at the physicians of his time and compares them with the alchemists in the following terms : 'For they are not given to idleness nor go in a proud habit, or plush and velvet garments, often showing their rings upon their fingers or wearing swords with silver hilts by their sides, or fine and gay gloves upon their hands, but diligently follow their labours, sweating whole days and nights by their furnaces. They do not spend their time abroad for recreations but take delight in their laboratory. They wear leather garments with a pouch, and an apron wherewith they wipe their hands. They put their fingers amongst coals, into clay, and filth, not into gold rings. They are sooty and black like smith and colliers, and do not pride themselves upon clean and beautiful faces.'

Even so late as the middle of the last century, the pursuit of Chemistry in England was not regarded in a serious light and 'chemists were ashamed to call themselves so because the apothecaries had appropriated the name'—a circumstance which led Liebig in 1837 to declare 'that England was not the land of science'.[19]

Thus when the physicians of Paracelsus' time became only fashionable social parasites,[20] representing science only in its

18. *Ibid* 112 ff.
19. P. C. Ray HHC Vol. I, 194 note.
20. It may be noted here that his real name was P.A. T.B. von Hohenheim (1493-1541) ; but he called himself Paracelsus to show contempt for Celsus, the great doctor of antiquity. To prove the supremacy of direct experience over any authority, he went to the extent of burning books of Galen and Avicenna in market-place. See J. D. Bernal, SH 398.

degeneration, Paracelsus himself saw in the alchemists' devotion to manual work the real hope of the rejuvenation of natural science. And it is here that we have the clue to one of the most significant factors that ushered in the spirit of modern science in Renaissance Europe—a phenomenon referred to by Ray as 'the sturdy sons of Europe eventually overcoming the dangers' created for science by this undesirable social phenomenon. Since P. C. Ray referred to this phenomenon—though cryptically and in his own way—we may as well turn to J. D. Bernal who has worked out the point in greater details, because the point itself is of crucial significance for our understanding of science in Indian history.

7. BACK TO BERNAL

Bernal wants us to note that one important factor accounting for the revival of science in modern Europe is that "the Renaissance healed, though only partially, the breach between aristocratic theory and plebeian practice." Elaborating the point he observes[21] :

> What was really new, however, was the respect given to the practical arts of spinning, weaving, pottery, glass-making, and, most of all, to the arts that provided for the twin needs of wealth and war—those of the miners and the metal-workers. The techniques of the arts were of more account in the Renaissance than in classical times because they were no longer in the hands of slaves but of free men, and these were not, as they had been in the Middle Ages, far removed socially and economically from the rulers of the new society. In medieval Florence, for instance, the artists had been subordinate members of the major guild of doctors and spice-dealers, *Medicie Speciali;* the sculptors were lower down with the minor guild of the masons and bricklayers. By the beginning of the sixteenth century, however, individual painters and sculptors could command the favours of popes and kings, though they often had to press hard to obtain payment for their work.
>
> The enhancement of the status of the craftsman made it possible to renew the link between his traditions and those of the scholars that had been broken almost since the beginning of the early civilizations. Both had a great contribution to make : the craftsman could add to the old techniques of classical antiquity the new devices that had arisen during the Middle Ages ; the scholar could contribute the world views, the ideas, and possibly most of all, the logical methods of argument derived from the Greeks by way of Arabic and scholastic

21. J. D. Bernal SH 386.

philosophy, and the newly evolved methods of computation. The combination of the two approaches took some time to work out, and spread rather gradually at first through the different parts of knowledge and action. But once the constituents had been brought together there was no stopping the combination—it was an explosive one. The intellectual task of the Renaissance was essentially the rediscovery and mastery of the world of art and Nature. .

8. SCIENCE AND PHILOSOPHY

But let us return to P. C. Ray. If he was the first working scientist in India to have rejected in his own way the "internalist hypothesis" by looking at the cause of the decline of scientific spirit in India not *within* science but *outside* it—in the development of a society requiring condemnation of manual work—let us not overlook the fact that he was also aware of the ideological or philosophical factors that worked as co-respondents to the downfall of the scientific temper in Indian history. Hence he felt that a critical review of the Indian philosophical situation was necessary in this connection. As he realised, among the Indian philosophical views, there were some that favoured science or the scientific spirit, just as there were others that were basically hostile to the requirements of natural science. Though not specialising in philosophy, Ray had evidently enough grasp of the Indian philosophical situation to differentiate between the two. Thus he could see that the philosophy of atomism, associated in the popular mind with the name of Kanada as its founder, had significant science-potential in ancient Indian context. He could also see that the world-denying metaphysics (*maya-vada*), generally known as Samkara's Vedanta, could not but be inimical to science. In P. C. Ray's judgement, therefore, Samkara, too, stood accused for the decline of science in Indian history—a judgment too courageous to pronounce in the Indian context, where Samkara's name often carries the epithet of being an incarnation of God. But Ray had the courage and he observed :

> The Vedanta philosophy, as modified and expanded by Samkara, which teaches the unreality of the material world, is also to a large extent responsible for bringing the study of physical science into disrepute. Samkara is unsparing in his strictures on Kanada and his system. One or two extracts from Samkara's Commentary on the *Vedanta Sutras*, will make the point clear : [Observed Samkara] 'It thus appears that the atomic doctrine is supported by very weak arguments only.

is opposed to those scriptural passages which declare the Lord to be the general cause, and is not accepted by any of the authorities taking their stand on scripture, such as Manu and others. Hence it is to be altogether disregarded by highminded men who have a regard for their own spiritual welfare.' [Again :] 'The reasons on account of which the doctrine of the Vaisesikas cannot be accepted have been stated above. That doctrine may be called semi-destructive (or semi-nihilistic)'.[22]

To this Ray added :

Among a people ridden by caste and hide-bound by the authorities and injunctions of the Vedas, Puranas, and Smrtis and having their intellect thus cramped and paralysed, no Boyle could arise to lay down such sound principles for guidance as : '...I saw that several chymists had, by a laudable diligence obtained various productions, hit upon many more phenomena, considerable in their kind, than could well be expected from their narrow principles : but finding the generality of those addicted to chymistry, to have had scarce any view, but to the preparation of medicines, or, to the improving of metals, I was tempted to consider the art, not as a physician or an alchymist, but a philosopher. And, with this view, I once drew up a scheme for a chymical philosophy ; which I shou'd be glad that any experiments or observations of mine might any way contribute to complete.

'.....And, truly, if men were willing to regard the advancement of philosophy ; more than their own reputations, it were easy to make them sensible, that one of the most considerable services they could do the world is, to set themselves diligently to make experiments, and collect observations, without attempting to establish theories upon them, before they have taken notice of all the phenomena that are to be solved'.[23]

Here, again, we come across a working scientist, while enquiring into the history of science in India, realising the need of analysing the interaction of science and philosophy. It cannot but be reminiscent of what J. D. Bernal observes only a few decades later, though Bernal—equipped as he is with scientific sociology—connects the philosophical controversy also with sociological interests. He observes[24]:

The general character of the theoretical controversy inside science is, however, not new. As will emerge clearly from a study of its history, a sometimes latent, sometimes active struggle has been going on ever since the dawn of science between two main opposing ten-

22. P. C. Ray HHC I. 195-6 note.
23. *Ibid* I. 196-7 note.
24. J. D. Bernal, SH 53-54.

dencies : one, formal and idealistic ; the other, practical and materialistic. We shall see this conflict as the dominant one in Greek philosophy, but it must have originated much earlier, indeed from the first formation of class societies, for the general social affinities of the two sides in the conflict have never been in doubt.

The idealist side is the side of 'order, the aristocracy, and established religion ; its most persuasive champion is Plato. The objective of science, in its view, is to explain why things are as they are and how impossible, as well as impious, it is to hope to change them in essentials. In Plato's mind all that is necessary is to remove a few blemishes, such as democracy, for the republic to be established safely for ever under the care of the guardians, the men of gold. As the perfections of this state of affairs may not be at once apparent to inferior ranks, it is necessary to prove to them the illusoriness of the material world and consequently the unreality of evil in it. In this imagined world, change is evil ; the ideal, the good, the true, and the beautiful are eternal and beyond question ; and as they are palpably not very prevalent on earth they must be sought for in a perfect heaven. This view has had a profound effect on the development of science, particularly in astronomy and physics, and even today, in more elaborate and sophisticated forms, there is again a strong tendency to enforce it on science.

The materialist view, partly because of its practical nature and even more because of its revolutionary implications, did not for centuries find much support in literate circles and rarely formed part of official philosophy. One expression of it, however, survives in Lucretius' Epicurean poem *De Rerum Natura* (on the nature of things), which shows both its power and its danger to established order. It is essentially a philosophy of objects and their movements, and explanation of Nature and society from below and not above. It emphasizes the inexhaustible stability of the ever-moving material world and man's power to change it by learning its rules. The classical materialists could go no further because, as we shall see, of their divorce from the manual arts ; nor could, in later days, the great reformulator of materialism, Francis Bacon. Once the Industrial Revolution was under way, science became in practice materialist, though continuing to give, for political and religious reasons, some lip service to idealism. Up to the middle of the nineteenth century materialism remained philosophically inadequate because it did not concern itself with society and its transformation, and was thus unable to account for politics and religion. The extension and transformation of materialism to include these was the work of Marx and his followers. First effective in the political and economic field, the new dialectical materialism is only now beginning to enter the sphere of the natural sciences.

The struggle between idealist and materialist tendencies in science has been a persistent feature in its history from earliest times. The idealism of Plato is in some sense an answer to the materialism of

Democritus, the founder of the atomic theory. In the Middle Ages, Roger Bacon attacked the prevailing Platonic-Aristotelian philosophy and preached a science aimed at practical utility and was imprisoned for his pains. In the great struggle of the Renaissance to create modern experimental science the prime enemy was formal Aristotelianism backed by the Church. The same opposition was to be found in the last century in the warfare between science and religion over Darwinian evolution. The very persistence of the struggle, despite the successive victories won by materialist science, shows that it is not essentially a philosophic or a scientific one, but a reflection of political struggles in scientific terms. At every stage idealist philosophy has been invoked to pretend that present discontents are illusory and to justify an existing state of affairs. At every stage materialist philosophy has relied on the practical test of reality and on the necessity of change.

To a section of readers, Bernal's way of connecting philosophical controversy not merely with theoretical issues *within* science but also with socio-economic factors apparently *outside* science may appear to be but a mark of his political preference and partisanism. It remains for us to see, however, whether the Indian situation really justifies it or not.[25]

For the present, let us return again to P. C. Ray and the tradition he wanted to set up.

9. M. N. SAHA

Among the "talented students" of the Presidency College who are indebted to P. C. Ray for their early initiation in modern science, M. N. Saha appears to be the most prominent one. He carried forward not only Ray's defence of science as a value in itself but also the superb insight of Ray into the relation of science and society. For this, Saha had to confront literally a barrage of attack from the champions of Vedic orthodoxy.[26] He was accused of showing only a slavish mentality in defending modern science flourishing in Europe, overlooking the fact that everything worthwhile in modern science is already to be found in the Veda-centric culture of ancient India, which in many ways was alleged to have been far ahead of modern "European" science for example, in developing the

25. I have, in my book SSAI, tried to show that this has also been the case in Indian history. We shall return to the point in the next volume of the present work.

26. See *Meghnad Racana Sankalan* (in Bengali) 117 ff.

caste system which was supposed to impart a kind of stability to society and hence enabled the Indians to evade the social turmoil of capitalist Europe. Saha had to waste much of his valuable time to clean up such rubbish.[27] We do not unfortunately have the scope here to quote the whole of it. But we shall mention here a few of his points, because of their bearing on what we are going to discuss later.

A point of exceeding importance raised and briefly discussed by Saha is that the champions of Veda-centric or Aryan culture somehow feel obliged to suppress or by-pass the recent archaeological work, which proves that while the Vedic people—apart from their literary work that often proves highly obscure for us today—left practically nothing worth mentioning as material achievements, there developed already at least a millenium before their coming to India an imposing civilization in the Indus valley which—at least according to a section of serious archaeologists—was finally destroyed by the invading Aryans. There are controversies, of course, about the decline and final destruction of the Indus Valley Civilization. Without entering into these, Saha raises a simple but significant question: Why do his opponents—the champions of the Vedas—prefer to remain silent about this glorious past of Indian civilization? Is it simply because of the fact that the makers of the Indus Valley Civilization were pre-Aryans and pre-Vedic?[28] It is understandable that P. C. Ray in his *History of Hindu Chemistry* did not raise this question, because the Indus Valley Civilization was discovered after its publication. But it is worth mentioning that outside the archaeologists, M. N. Saha is about the only notable scientist who, already in 1939, found it worthwhile to write a longish article in *Science and Culture* on "The Indus Valley 5000 years Ago".[29] It remains for us to see why all this is of material importance for our own understanding of the history of science and technology in Indian history.

27. *Ib.* 108-189. These writings still remain in Bengali and it seems highly desirable that these should be rendered into English for readers outside Bengal.
28. *Ib.* 128.
29. M. N. Saha in SC Vol. V No. 1 July 1939 and Vol. V No. 2, August, 1939.

No less important is Saha's observation on the causes that inhibited the development of modern science in India—an observation in which he carries forward the view already expressed by P. C. Ray. We quote him, though inevitably missing much of the force of his argument in our rough English translation. Refuting the alleged benefits of the caste system, Saha observes :

"But I have looked at the matter from a different angle. In my view the caste system has completely snapped the connecting link between the hand and the brain, and this is why the material culture of India is lagging far behind that of Europe and America. One who belongs to the intelligentsia is perpetually busy with bookish knowledge, commentaries, glosses and grammatical debates ; the ideal for the medieval Indian scholars was to create awe among the people with the extent of their learning. They had little connection with real life. They never cared for the development of industry and commerce, which perhaps carried the risk of being degraded in caste hierarchy".[30] By contrast, adds Saha, Hargreaves was an illiterate labourer, Arkwright a pennybarber, Cartwright a village clergy ; James Watt was a smith running a repairing-shop—it was because he came in contact with Professor Black of Glasgow University that he was able to invent steam engine.

As against all this, his orthodox critic—hitting as it were below the belt—argued that neither Megh Nad Saha nor Rabindranath Tagore is a craftsman ; will then the social status of a skilled shoemaker or weaver be higher than them? Saha's answer to this is a bitter one. What he is arguing is a different point altogether. "Why", he asks, "should be the social prestige of an illiterate priest—who, without really knowing the meaning of the Sanskrit verses, make others mutter these during the marriage or *Sraddha* ritual—be higher than a weaver or shoemaker? After all, the weaver or the shoe-maker serves the society with his labour ; but what else can you possibly say about the illiterate priest than a social cheat?"[31]

Saha's passionate defence of manual work and his emphasis on the need of the unity of head and hand as an essential pre-

30. *Meghnad Racana Sankalan* (in Bengali) 132.
31. *Ib.* 133.

condition for scientific development cannot but be reminiscent of the teachings of P. C. Ray. So also in a sense, his way of looking back at the Indian philosophical tradition and its impact on science. Thus, for example, when Ray argued that the overwhelming influence of Samkara's Vedanta, with its attempted suppression of the atomic hypothesis, had only an inhibitory influence on the scientific activities in India, Saha wants us not to forget the fact that this Vedic philosophy had not been the only one in the general fund of Indian philosophical thought, evidently implying that the genuine national sentiment may as well look to other directions in philosophy that could better cater to the requirements of our national development. the focal point of which in Saha's view is of course the development of modern science and technology. Addressing his orthodox critic who insists on the exclusive glory of the Vedas, Saha asks : "Is he not aware of the fact that both Buddhism and Jainism, which ushered in the most glorious periods of Indian civilization have completely rejected the Vedas as but a bundle of errors? Is he not aware of the fact that, according to the Lokayata view, 'These makers of the Vedas are but cunning cheats and thieves?' All this means that sometimes before Christ, there was a group of rationalists who could realise that it was extremely difficult to comprehend the actual meaning of the Vedas; only a few hypocrites propagate erroneous views with the alleged sanction of the Vedas. So to seek the roots of Hindu religion and philosophy only in the Vedas is about ninety per cent erroneous and it is this error that makes the essay of the critic full of mistakes".[32]

10. SCIENTIFIC METHOD

To quote the authority of the Lokayata philosophy with approval tacit or otherwise—is perhaps the limit of heresy from the orthodox point of view.[33] Nevertheless, from the standpoint

32. *Ib.* 130.

33. How the Indian philosophical literature is almost saturated with the contempt for Lokayata is too well-known to be mentioned here. See D. Chattopadhyaya *Lokayata : A Study in Ancient Indian Materialism.* Incidentally, in a Bengali article written by P. C. Ray also there seems to be a tacit approval of the Lokayata view : reprinted in *Utsa Manus* (Bengali), Sept. 1984, pp. 229-30.

of science there appears to be some justification for it. Among the philosophical views of traditional India, Lokayata is about the only one that puts an uncompromising emphasis on direct observations as the primary way of knowing, so much so that the other philosophers usually depict it as accepting immediate perception as the only source of right knowledge and therefore reject even inference as a way of knowing—a position that creates obvious difficulties in philosophical investigation. It remains for us to see whether the opponents of Lokayata are justified in imputing to it such an exclusive emphasis on direct observation, i.e. to the exclusion of the validity of worldly or normal inference, for there are enough indications in the Indian philosophical literature to think that the representatives of Lokayata were only insisting on the primacy of perception and were prepared to accept the validity of inference, though only in so far as it was based on perception.[34]

For the present, however, our point is a different one. To the scientists and also to the historians of science in India, there is obvious reason to look back at the Lokayata emphasis on the primacy of perception or direct observation with some enthusiasm, specially in the general intellectual climate of a country characterised by an almost suffocating scripture-mongering. In direct contrast to this tendency of accepting the scriptures as embodying ultimate wisdom, science demands that the starting point of its method is the interrogation of nature by direct observation. This is why, as we have already seen, P.C. Ray himself enthusiastically quoted two alchemists—Ramacandra and Yasodhara—because of their claim of putting very strong emphasis on direct observation, adding: "Experiments and observations constitute the fundamental bases of sciences."

All this leads us to consider the question of scientific method in Indian tradition. From P.C. Ray's *Autobiography*[35] we learn that while working on the *History of Hindu Chemistry* he felt the need of the cooperation of B. N. Seal (1864-1938): certain basic questions pertaining to the history of science in India remain embodied in texts that are viewed as philosophical ones in the restricted sense. In spite of a very wide range of his

34. D. Chattopadhyaya *Lokayata* 22 ff.
35. P. C. Ray *Auto.* 132.

own studies, these philosophical texts are often too technical to be tackled by Ray himself, specially because of his own multifarious activities. During his time, B.N. Seal had the reputation of an encyclopaedic mind, specially in matters concerning the Indian philosophical texts. It was, therefore, only natural for Ray to seek Seal's cooperation and get two chapters to contribute to Ray's *History*. Seal wrote these two chapters, which first appeared as incorporated in Ray's *History* and seem to have formed the starting point of Seal's own book, which was eventually published with the title *The Positive Sciences of the Ancient Hindus* (London 1915). As B.N. Seal put it in his foreword to it : "The chapter on the 'Mechanical, Physical and Chemical theories of the Ancient Hindus' appeared in P. C. Ray's *Hindu Chemistry* and that on the 'Scientific Method of the Hindus' as an appendix to the same work".[36]

We have mentioned this specially to emphasise one point. Ray evidently felt that a history of science, in order to be scientific, was in need of a survey of the scientific method. It remains for us to see that Seal's own understanding of the methodology of science—like his reading of various aspects of scientific development in ancient India—seems to be in need of serious revision, notwithstanding its historical importance as the first attempt at a comprehensive reconstruction of the scientific method from the Indian sources. Before we pass on to it, however, there remains for us to note another point, which appears to be rather sad, if not a positive misfortune.

11. IDEOLOGICAL RETREAT

Thanks to the initiative of S.S. Bhatnagar—whom Ray proudly calls "my chemical grand pupil"[37]—and with the active cooperation of J.C. Ghosh and J.N. Mukherjee, there came into being in 1924, The Indian Chemical Society, with P.C. Ray as its first president.[38] In view of the fact that Ray's *History of Hindu Chemistry* has become somewhat dated in 1948 the Indian Chemical Society resolved to publish "a revised edition of the book". "It was further resolved that the new publication should

36. B. N. Seal PSAH Preface iii.
37. P. C. Ray *Auto.* 130, also note.
38. *Ib.* 152-53 & 157-8.

incorporate all important additional materials that had since been brought to light, and that its name should consequently be changed to *History of Chemistry in Ancient and Medieval India*".[39] The task of the preparation of this new version was assigned to Priyadaranjan Ray—a direct disciple of P.C. Ray, about whom P. C. Ray himself expressed high hopes as a young chemist with much promise.[40] As edited by him this new book appeared in 1956, claiming in its title page to "incorporate" P. C. Ray's *History of Hindu Chemistry*.

It would be wrong, of course, to take a totally negative attitude to Priyadaranjan Ray's new version of the history of chemistry in India. When, for example, P.C. Ray wrote his *History*, nothing was known about the imposing Indus Valley Civilization, the material remains of which are being unearthed only from the third decade of the 20th century. These are indicative of high technological achievements, inclusive of some that are significant chemical operations. Descriptive accounts of some of these are rightly given in the new book. So also are incorporated in it some alchemical texts which P.C. Ray could not consult. Specially interesting among these are the works that are irrevocably lost in the Indian originals and survive only in Tibetan version.[41]

However, such important additions notwithstanding, the new book gives us the sad impression of some kind of ideological retreat—retreat specially from the scientific temper on which P.C. Ray puts so much emphasis. It is, for example, strange to see in this book allegedly incorporating P.C. Ray's *History*, the entire chapter on Scientific Method by B.N. Seal summarily scrapped. Even some of P.C. Ray's own observations on the methodology of the alchemists are just brushed aside. Of the two alchemists so enthusiastically quoted by P.C. Ray for their scientific temper, Ramacandra does not receive even a cursory mention in the new book. The other alchemist quoted by P.C. Ray, Yasodhara, has some place in the new book. We find him being mentioned five times (and even his *Rasaprakasa-sudhakara* is given in extracts), but *nowhere is mentioned the*

39. P. Ray HCAMI. Foreword p. E.
40. P. C. Ray *Auto.* 155.
41. P. Ray HCAMI 449 ff.

strong emphasis he put on direct observation and experiment or, according to the alchemists' way of putting the latter, on personally performing an operation as a precondition for accepting a chemical or proto-chemical proposition.

The new book in fact shows some worse features from the viewpoint of the scientific temper. In the general fund of Indian philosophical thought, there are views going strongly against the requirements of science. P.C. Ray found the most prominent of these in the world-denying philosophy (*maya-vada*) of Samkara's Vedanta. Hence he sharply came out against it, arguing that the great prestige and popularity of this philosophy was an important factor accounting for the decline of the scientific spirit in India. Peculiarly enough, Priyadaranjan Ray, in his allegedly revised version of P.C. Ray's *History*, chooses to expunge the entire comment of P.C. Ray on the adverse effect of Samkara's Vedanta on the development of science in India. That is hardly the way of editing a book—specially one that has acquired the status of some kind of classic among the recent works on Indian science.

All this, however, seems to be a matter more serious than that of mere editorial norm. The conscious suppression of P.C. Ray's observations of Samkara's Vedanta seems to be indicative of an ideological retreat from the bold defence of science and the scientific temper of P.C. Ray. Following Samkara's own claim, this philosophy is proclaimed in the country for centuries as having the highest scriptural sanction. Many of our contemporary philosophers continue to be under its spell, producing tons of books in defence of the philosophy. To be critical of it amounts to many as some kind of sacrilege, if not a sin.

12. HINDU REVIVALISM

We can thus see where exactly is the rub. If, in defence of science, P.C. Ray found it necessary to come sharply against the world-denying philosophy of Samkara, the editor of his book seems to seek safety in maintaining a discrete silence about the whole thing. The result is that, though giving us a somewhat enlarged account of the chemical and proto-chemical techniques in ancient and medieval India, Priyadaranjan Ray prefers to avoid the troublesome question of the

scripture-oriented philosophy coming in open confrontation with the basic requirements of natural science. Does it not amount to aiding and abetting Hindu revivalism, which P.C. Ray himself considered fatal for the country? In his *Autobiography*, he found it necessary to write a special section on "The Revival of Hindu Orthodoxy Fatal to the Progress of India".[42] We quote an extract from it :

Our excellent friends, the Hindu revivalists, will talk by the hour on the transcendental truths and sublime thoughts in the *Gita* and deliver elaborate discourses on the catholicity of Hinduism and its superiority over all other existing creeds ; will condemn untouchability in unmeasured terms and so on. When, however, it comes to carrying the precepts into practice, they are the first to show the white feathers ; as Professor Wadia puts it :—

'Our Vedantist will flood you with quotations to show how catholic Hinduism is, but woe to the man who dared to take this seriously and ever acted upon them. Quotations are for show, not for action. In fact, I believe so much precious time has been wasted in proving that Hinduism is cosmopolitan, is catholic, that no time has been spared for the practice of it. Fear leads to repressions and without its conquest no man can find himself or rise to his full stature'—*Presidential Address at the Philosophical Congress (Dec. 1930)*.

No wonder that in spite of the empty vapourings of the Hindu Sabhas and Sangathans, conversion to Islam goes on day by day as ever. And why should it not ? Islam knows no distinction of race, colour, or creed as far as social matters are concerned. Untouchability it is a stranger to ; it is a 'perfect equaliser of men', as Carlyle has it..... No wonder our friends the *Namasudras* are tired of the hypocritical assertions of the Hindu leaders and are sometimes eager to seek shelter in the bosom of Islam.[43]

Whether Islamic fundamentalism is having in the world today an adverse effect on the progress of science, is, of course, a different question. Fundamentalism in any form is indeed anti-science, and in any case what Ray referred here was to an altogether different aspect of the message of Islam. What proved specially difficult for the development of science in India in his time was Hindu revivalism. That is evidently one of the reasons why he put special emphasis on the need of scientific method which could be an effective antidote to religious revivalism in all forms.

42. P. C. Ray *Auto.* 434.
43. *Ib.*

13. B. N. SEAL ON SCIENTIFIC METHOD

As already mentioned, P.C. Ray considered it desirable to depend on B.N. Seal for a comprehensive survey of the scientific method in Indian tradition and we are not aware of any other scholar before Seal attempting to treat the subject seriously. But this pioneering study in the scientific method seems itself to be in need of a scientific scrutiny.

B.N. Seal opened his own discussion of the Scientific Method in Indian thought with a strong defence of it, and, what is more important, he wanted to draw our attention to the fact that, according to some Indian thinkers at any rate, the main point about it is that practice is the criterion of truth. As he put it :

> A study of the Hindu Methodology of Science is absolutely essential to a right understanding of Hindu positive Science, its strength and its weakness, its range and its limitations. Apart from this rigorous scientific method, Hindu Chemistry, for example, would be all practical recipe, or all unverified speculation. This, however, would be a very inadequate and indeed erroneous view of this early achievement of the human mind. That the whole movement was genuinely and positively scientific, though arrested at an early stage will appear from the following brief synopsis of the Hindu Methodology of Science.
>
> *Criterion or Test of Truth, after the Buddhists* :—The ultimate criterion of Truth is found, not in mere cognitive presentation, but in the correspondence between the cognitive and the practical activity of the Self, which together are supposed to form the circuit of consciousness. That knowledge is valid which prompts an activity ending in fruition. (Cf. the distinction between *samvadi* and *visamvadi jnana*. Also compare *pravrtti-samarthyat arthavat pramanam*—Vatsyayana). Truth, the Buddhists contend, is not self-evidence, not the agreement between ideas, not the agreement of the idea with the reality beyond, if any, for this cannot be attained direct, but the harmony of experience (*samvada*), which is implied when the volitional reaction, that is prompted by a cognition and that completes the circuit of consciousness, meets with fruition, i.e. realises its immediate end (with this compare Sriharsa, *Khandana Khanda Khadya*, on the relation of *prama* to *loka-vyavahara*). This is the material aspect of Truth. The formal aspect is given in a principle which governs all presentations in consciousness, and which combines the three moments of Identity, non-Contradiction, and Excluded Middle in every individual cognitive operation [*taduktam tat paricchinatti* (identity), *anyad vyavacchinatti* (non-contradiction), *trtiya-prakarabhavam ca sucayati* (excluded middle)

iti ekapramana-vyaparah—Jayanta, *Nyayamanjari, pramana-dvaividhya-khandanam*].[44]

We have quoted all this for the purpose of focussing on one point. At least as understood by the earlier generation of our scientists and thinkers like P.C. Ray and B.N. Seal, any attempt to write a history of science in India along with a total neglect of the scientific method cannot be legitimate. That, in other words, would be following a wrong model for the history of science. From this point of view, therefore, it is unfortunate that such a false model has become the dominant one for the later writers on the history of science in India. An example of this is the imposing volume sponsored by the Indian National Science Academy and published under the title *A Concise History of Science in India*.[45] It professes to give us an impressive account of the achievements of the ancient Indians in mathematics, astronomy, medicine, and so on, without anywhere seriously raising the question concerning the scientific way of knowing or of the methodology followed by the ancient Indians for moving in the field of science proper. The result is worse than indiscriminately jumbling up technology with science. The indifference to scientific method allows even patently a-scientific and anti-scientific ideas and attitudes to enjoy the same status as that of science, as is evident, for example, in the tendency to read in this book science in all sorts of predominantly religious texts.[46] Such a danger could have been easily avoided if only the editors and contributors to this book cared to remember the elementary point already emphasised by P.C. Ray and B.N. Seal that there is no real science without the methodology of science.

14. LIMITATIONS OF B. N. SEAL

But let us return to B.N. Seal's study of the scientific method in ancient India. As against the prevailing but eclectic tendency

44. B. N. Seal PSAH 244-45.
45. Practically the same model was followed by Th. Stcherbatsky in "Scientific Achievements of Ancient India" (See SHSIA 3-22) and B. K. Sarkar in his *Hindu Achievements in the Exact Sciences*, New York and Calcutta 1918.
46. It needs to be acknowledged, however, that as a compilation of useful information about scientific activities in India the volume continues to have its importance.

to discuss the history of science in India without taking note of the scientific method, the importance of the main point on which he put special emphasis can hardly be exaggerated. So also is the significance of many of his observations on the scientific method in ancient India, which are perhaps only to be expected of the encyclopaedic erudition of B.N. Seal. However, specially for the purpose of our understanding of the problem of the *emergence of science* in ancient India, it may be useful for us to begin with a few points which, though extremely relevant to the methodology of science, escaped his attention.

Here is a preliminary enumeration of some of these :

First. the scientific method—like science itself—is a growing process, and hence it would be wrong to expect it as fully formulated at any stage of the history of ideas.

Secondly, the commitments to the scientific method—like the commitment to science itself—is often a matter of active struggle, because there is also some such thing as anti-science with its own methodological prerequisites.

Thirdly, the struggle between the scientific method and its opposite, though manifesting itself mainly at the level of theoretical considerations, is ultimately rooted in concrete social conditions, without noting which even the most erudite compilation of bare textual data runs the risk of petering out in puerile pedantry.

Let us begin with some clarification of the first of these points. Scientific method does not mean any royal road to Scientific Truth, which is discovered once for all, leaving the scientists only with the task of properly following it. As J.D. Bernal[47] has very lucidly put the point :

> There is a danger of considering it [i.e. the scientific method] as a kind of ideal Platonic form, as if there were one proper way of finding the Truth about Nature or Man, and the scientists' only task was to find this way and abide in it. Such an absolute conception is belied by the whole history of science, with its continual development of a multiplicity of new methods. The method of science is not a fixed thing, it is a growing process. Nor can it be considered without bringing out its closer relations with the social, and particularly the class, character of science. Consequently scientific method

47. Bernal SH 35.

like science itself, defies definition. It is made up of a number of operations, some mental, some manual. Each of these in its time, has been found useful, first in the formulation of questions that seem urgent at any stage and then in the finding, testing and using the answers to them.

In view of the refinements and ramifications of the methodology in the subsequent course of the history of science, it may be useful to add to the above another point. Specially for understanding science in the ancient world—though also partly for disentangling scientific method from the dregs of some metaphysical views with which science is intertwined in the writings of many modern writers—it is useful and in a sense even crucial—to analyse the first step taken from pre-science to conscious science. When we look back at it and wrongly judge it in the standard of modern knowledge, we may have the impression of this having been a trivial one. But such an impression would be most misleading. Historically speaking, the first step to science is indeed the most prodigious one, for it requires the profoundest transformation in the totality of ideas and attitudes.

With all his emphatic assertion of the importance of the scientific method, B. N. Seal does not take note of these points. For his own understanding of the scientific method in ancient India, he began straightway with a class of texts—inclusive of much later ones—which, in default of a better descriptive epithet, are usually called texts on "logic". Some of these were written by philosophers belonging to the Nyaya school, some others by a section of philosophers professing the Buddhist creed.[48] Depending mainly on these texts, B. N. Seal proposed to construct his own account of the scientific method in ancient India.

There was some real ground no doubt for his procedure. The writings of these "logicians" are indeed for us the most outstanding works discussing many questions considered essen-

48. Seal's somewhat omnibus use of the word "Buddhist" cannot but be confusing. Among the numerous Buddhist sects, only the one represented by Dignaga and his followers took a positive interest in "logic" and "scientific method", though for this purpose they had to suspend, as it were, their enthusiasm for extreme subjective idealism. See, D. Chattopadhyaya WLWDIP 56 ff.

tial for the methodology of science in the nineteenth century Europe. Such, for example, was the question concerning the establishment of materially true universal real propositions which, in its turn, called for a good deal of discussion about the technique of determining the causal connection. The Indian philosophers went into much details of all these which, B. N. Seal energetically argued, made their position much more advanced than that of the bare formal logic of Aristotle and in fact anticipated the Inductive Methods of J. S. Mill.

15. SCIENTIFIC METHOD AND THE WORKING SCIENTISTS

However, admitting all that is really substantial in B. N. Seal's discussion, he leads us to an apparently peculiar situation. Notwithstanding all their interest in epistemology, the writers on whom Seal depended were philosophers after all. There is nothing improbable, of course, about some philosophers taking interest in the scientific method, as many of the contemporary philosophers are ostensibly doing. What is odd, however, is to think that the methodology of science could develop *totally outside the circle of the working scientists* or irrespective of the experience of the scientists themselves. How, then, could the scientists themselves possibly work? Could they work without the need of any scientific method—a possibility that makes the very concept of scientific method a misnomer? Alternatively, we have to imagine that the scientists had first of all to learn their methodology from the philosophers before engaging themselves to their own research. Evidently, there can be no ground to take such a possibility seriously. Besides, it is not easily conceivable that the philosophers could be taking an interest in the methodology of science already *before* the emergence of science or without there being a general theoretical climate created by the development of science at least upto a certain stage. Evidently again, the methodology of science cannot be the product of pure reason or sheer speculative considerations, which the philosophers are supposed to be left with in default of the development of natural science. In short, one can hardly be serious about the very concept of the scientific method, ignoring at the same time the possibility of the working scientists participating in its making.

The obvious way out of this difficulty is to think that the emergence of science took place in ancient India already *before*

the "logicians". This means that the real pioneers of science had an understanding of their own methodology, though it was left for the "logicians" to elucidate, elaborate and systematise the theoretical implications of this methodology. It remains for us to see how far historically speaking such could possibly be the real situation. The very structure of the earliest work on Indian "logic" (*Nyaya-sutra*) seems to presuppose a theoretical climate in which natural science was developed enough to knock, as it were, for new doors to be opened in philosophy for more adequate understanding of the scientific method.[49] But B. N. Seal did not concede to this possibility. Therefore, with all his emphatic assertion that the scientific activities in ancient India cannot be understood without the appreciation of the scientific method, he was virtually led to the assumption that the scientific method somehow or other developed *before* natural science among the philosophers, from whom the natural scientists borrowed it. Let us see how he committed himself to such a position.

Though nowhere facing the historical question of the actual formation of the scientific method, B. N. Seal was obviously aware of the fact that the *Caraka-samhita*—which comes down to us as the earliest compilation of medical science in India—contains a fairly elaborate discussion of the scientific method. How is this to be explained? Does it mean that the ancient Indian physicians—in the capacity of working scientists—developed a methodology that suited their purpose? Or, does it mean that they borrowed it from some other quarter? B. N. Seal argued in favour of the second possibility. To reconcile the evidence of the *Caraka-samhita* with his preconceived notion that the scientific method was actually worked out by the philosophers or logicians, he wanted us to believe that the physicians themselves found this method already worked out, awaiting only to be *applied* to their own field of work. He introduced two terms to explain this: *Logic* and *Applied logic*. The first meant the scientific method in its most general

49. S. N. Dasgupta's hypothesis that the Nyaya logic might have originated from the methodology of ancient Indian medicine may give us a useful clue to the primary stock of empirical logic presupposed by Nyaya.

sense or having a universal applicability. The second meant the same method as used by a section of scientists to meet their specific requirements. With this terminological innovation, B. N. Seal argued[50] :

> I will conclude with a few observations on Applied Logic, i.e. the logic of the special sciences which is such a characteristic feature of Hindu Scientific investigation. What is characteristic of the Hindu scientific mind is that, without being content with the general concepts of science and a general Methodology, it elaborated the fundamental categories and concepts of such of the special sciences as it cultivated with assiduity, and systematically adopted the general principles of Scientific Method to the requirements of the subject-matter in each case. The most signal example of applied logic (or Scientific Method) worked out with systematic carefulness is the Logic of Therapeutics in Caraka, a logic which adopts the general concepts of cause, effect, energy, operation, etc. and the general methodology of science, to the special problems presented in the study of diseases, their causes, symptoms and remedies.

The argument is peculiar indeed, for it amounts to the claim that some philosophers in ancient India could somehow discover some royal road to Truth without being bothered by the rigor of systematic investigation of any department of nature. Even admitting this, what could be the justification of equating it to the methodology of science?

From the standpoint of natural science, B. N. Seal in fact wanted us to believe in something more strange than this. Assuming, as he did, that the scientific method was the product of the philosophers' brain, he had no hesitation in viewing it as some kind of universal solvent of all problems, i.e. not merely of the problems of natural science but even that of attaining the highest metaphysical illumination. As he put it[51] :

> This doctrine of Scientific Method, in Hindu Logic, is only a subsidiary discipline, being comprehended under the wider conception of Methodology, which aims at the ascertainment of Truth whether scientific (*vijnana*) or philosophical (*jnana*) ; the latter being the ulterior aim.....Now the various *Pramana*-s, proofs, i.e. sources of valid knowledge, in Hindu Logic, viz., Perception, Inference, Testimony, Mathematical Reasoning (*Sambhava*, including Probability in one

50. B. N. Seal PSAH 290-1.
51. *Ib.* 289-90.

view), are only operations subsidiary to the ascertainment of Truth (*tattvanirnaya*). And the Scientific Methods are merely ancillary to these *pramana*-s themselves.

All this appears to be worse than considering scientific method "as a kind of ideal Platonic form", against the possible danger of which we have already quoted the warning of J. D. Bernal.

16. S. N. DASGUPTA

But this does not mean that others among the recent interpreters of Indian philosophical tradition simply echoed Seal's views. In the second volume of *A History of Indian Philosophy*, S. N. Dasgupta proposed a hypothesis which in fact amounts to the very opposite of that of B. N. Seal. While, according to the latter, the original architects of the scientific method in India were the logicians from whom the physicians borrowed it, Dasgupta raised the rather unusual question: "Did logic originate in the discussions of the Ayurveda physicians?"[52] The answer to this, according to him, is presumably in the affirmative. Before passing on to quote him at some length, let us have a few preliminary clarifications.

The earliest extant work on Indian "logic" is the *Nyaya-sutra*. It is attributed to a certain Aksapada (also called Caranaksa by Samkara), literally "One with eyes on the feet" About him—some legends apart—we known practically nothing. Even the very name Aksapada could be a sarcastic innovation[53] of the pure spiritualists, because of his essentially mundane interest: one with eyes on the feet could hardly have any vision of the lofty metaphysical wisdom. Nor do we know the exact date of the *Nyaya-sutra*, which is usually conjectured to be roughly the second century A.D.[54] Though the modern scholars have various views about the history of the formation

52. S. N. Dasgupta HIP ii. 373 ff.
53. D. Chattopadhyaya *Bharatiya-darsana* (in Bengali) 25.
54. It must be remembered, however, that the actual formation of the Nyaya logic must have been much earlier than its codification in the form of the *Nyaya-sutra*. Besides, the *Nyaya-sutra*, in the form in which it reaches us, is full of later grafts—inclusive of grafts of palpably alien ideas. See D. Chattopadhyaya, Introduction to *"Indian Philosophy in its Sources, Vol. I, Nyaya"*, Calcutta 1982.

of the extant *Nyaya-sutra*, the fact remains that we have no positive or definite knowledge about the origin of Nyaya logic. S. N. Dasgupta, however, points to certain exceedingly interesting internal evidences of the Nyaya literature, the possible implication of which cannot be overlooked. As he put it, "Incidentally it may be mentioned that Jayanta, in his *Nyaya-manjari*, discussing the probable sources from which Aksapada drew his materials, suggests that he probably elaborated his work from what he may have gathered from some other science (*sastrantarabhyasat*) ; but it is difficult to say whether by *sastrantara* Jayanta meant Ayur-veda. The *Nyaya-sutra*, however, expressly justifies the validity of the Vedas on the analogy of the validity of Ayur-veda".[55]

Though belonging to a somewhat late period (*c.* A.D. 900), Jayanta is regarded as a highly authoritative exponent of the Nyaya view. His suggestion that Aksapada might have received the fundamentals of the Nyaya view from some other science (*sastrantara*) cannot be easily dismissed, specially when we remember that the very structure of Nyaya logic presupposes the accumulation of a good deal of empirical knowledge and can by no means be the product of pure reason. In ancient India, as we shall later see more fully, medicine or Ayurveda was about the only science that showed the most absorbing interest in a vast amount of empirical knowledge. Thus the possibility cannot be easily dismissed that Jayanta might have had Ayurveda in mind when he said that Aksapada could draw his basic materials from *sastrantara* or "other science". All this seems to be all the more plausible, because we read in the *Caraka-samhita* extensive discussions concerning the problems of scientific method—"logic" or "proto-logic".

But more of this later. For the present we have mentioned all this only to emphasise the point that one of the foremost historians of Indian philosophy suggests the possibility of the scientific method in India developing among working scientists rather than among the metaphysicians searching for a royal road to ultimate truth.

On this point, therefore, B. N. Seal's exposition of "The Scientific Method of the Hindus" appears to be in need of serious amendment, notwithstanding the circumstance of Seal

55. S. N. Dasgupta HIP ii. 399.

having been the pioneer in discussing it in modern times and in putting very strong emphasis on its importance for our understanding of the history of science in India. Indeed, he tacitly assumed that the Scientific Method of the Indian thinkers was something more than was needed to meet the requirement of science, inasmuch as it was, in his view, some royal road to absolute Truth. As we have already quoted him claiming, "The doctrine of Scientific Method, in Hindu Logic, is only a subsidiary discipline, being comprehended under the wider conception of Methodology which aims at the ascertainment of Truth, whether scientific (*Vijnana*) or philosophical (*Jnana*)." Such an absolutistic or quasi-absolutistic view of the Scientific Method creates a number of difficulties in the understanding of the history of science, some of which may be noted here.

If the ancient Indians did in fact develop a method for ascertaining Truth (with a capital T), there remained little or nothing for them to learn from the scientific activities of the other nations, i.e. they remained cut off from the mainstream of international science to which various nations in various periods did contribute and from which all nations are required to—and, as a matter of fact, historically did—acquire elements for development and nourishment. In other words, Seal's understanding of Scientific Method in India carried on its heels the risk of making Indian science a rather closed body of Truth and thus lose the perspective of the current of international science.

17. MAINSTREAM OF GLOBAL SCIENCE

From this point of view, Seal seemed to have overlooked P. C. Ray's position who, in his own way, visualised the mainstream of global science into which the contributions of various countries flowed in various periods. Here are some of his observations, from which our chauvinists have much to learn.[56]

> That vigorous and robust thinking which characterised the days when the six systems of Hindu philosophy had been elaborated and which has very aptly been styled the Rationalistic Age had been for ages a thing of the past. Hindu intellect came to be under the domination of scholastic philosophy and revelled in the dialectics of

56. P. C. Ray *Auto.* 114-17.

the schoolmen and a sort of learning was in vogue under which, to quote the happy words of Buckle, the more learned the votaries were the more ignorant they grew.....

In the history of nations it is often found that contact of one civilisation with another brings about strange and on the whole beneficial results. Proud Rome did not disdain to learn at the feet of vanquished Greece. Alexandria [was] favoured by her position as the meeting-place of the Eastern and Western nations ..... besides the exchange of commercial products there was also an interchange of thoughts.

Borrowing does not always mean slavish imitation or lack of originality. As Emerson says : 'The greatest genius is the most indebted man'.....

The development and enrichment of Arabic literature may be cited here as a notable illustration. The orthodox and Umayyad Caliphates are from the intellectual point of view barren. It was however during the Abbasid rule that the many sided life of the Moslems found full expression and vigour in a copious literature which was enriched by wholesale borrowing from Greece. Under Caliphs Mansur and Mamun, Hellenic culture found full scope. The works of Aristotle, Plato, Galen, Ptolemy as also of the neo-platonists Plotinus and Porphyry were translated often from the Syraic versions as also direct from the Greek text. Among the Falasifa school (i.e. those who read in the original Greek) the names of Al-Kindi, Al Forabi, Ibn Sina (Avicenna), Al Razi (Rhazes) as also the Spanish philosopher Ibn Rhshd (Averroes) who flourished in the 12th Century A.D., stand conspicuous.

'This material expansion (in trade) was accompanied by an outburst of intellectual activity such as the East had never witnessed before. ...In quest of knowledge men travelled over three continents and returned home, like bees laden with honey, to impart the precious stores which they had accumulated to crowds of eager disciples, and to compile with incredible industry those works of encyclopaedic range and erudition from which modern science, in the widest sense of the word, has derived far more than is generally supposed'. The contributions of the Arabs in the domain of philosophy and science in the middle ages need not be dwelt upon here, nor it is necessary to mention that in mathematics and medicine they are deeply in debt to India.

The Arabs in their palmy days were in turn the bringers of light to mediaeval Europe and wielded an enormous influence on Latin scholasticism. A separate chapter may be written on the reciprocity of intellectual debt between Asia and Europe.

It remained for M. N. Saha, the able pupil of P. C. Ray, to carry forward the main argument of Ray. As against the orthodox chauvinists claiming to read everything worthwhile in

contemporary science in the Indian scriptures—specially the Vedas—Saha shows how much of the scientific activities in India was actually enriched by those of abroad. One way Saha shows this is by concentrating on the field of his own specialization, namely astronomy. Remaining fully aware of the achievements of the Indian astronomers specially as judged in their own historical context, Saha shows that from the time of the Sakas (*c.* A.D. 100) to that of *pandit* Jagannath, the court astronomer of Jay Sihgh in the 17th century A.D., there was repeated effort in India to improve astronomical knowledge by way of absorbing the best results in the field achieved abroad. We shall see some detail of all this in our own discussion of the development of astronomy in ancient India.

18. EUROPE-CENTRISM

If on the authority mainly of P. C. Ray and M. N. Saha we have so far tried to argue how wrong are the Indian chauvinists refusing to see the history of science as an international stream to which different nations contributed in different periods, let us not forget the other side of the picture, namely the somewhat arrogant claim of most of the European historians of science, namely that science itself is an essentially European phenomenon. We begin with a brief outline of their position.

With the first foreshadowing of modern science in Europe in the sixteenth century, there also grew the tendency of working backward and trace the beginnings of scientific thought to the achievements of Mediterranean antiquity. This direct linking of modern science with the ancient Greek tradition is increasingly utilised by a flourishing literature in the cause of a rather simplified understanding of the history of global science.

The story, we are told, began with some kind of Greek "miracle" resulting in the dawn of science. Not that the facts of the older civilisations—of Egypt and Mesopotamia, and, in recent years, also of the Indus—are denied. But these are mentioned cursorily and mainly for the purpose of showing why there could be no real science before the Greeks. As Arnold Reymond[57] says, "Compared to the empirical and frag-

57. A Reymond, *Science in Greco-Roman Antiquity*. Quoted by B. Farrington. GS 16.

mentary knowledge which the peoples of the East had laboriously gathered together during long centuries, Greek science constitutes a veritable miracle."

After an exciting career of about seven hundred years in Greece, Alexandria and Greco-Roman world, science is said to have suffered an eclipse, resulting in the darkness of the middle ages. The darkness prevailed over a thousand years. Then there was the illumination of Renaissance Europe, when the old Greek tradition was taken up again and conditions were created for the rise of modern science, with an ever-increasing rate of progress since then.

This, in brief, is supposed to be the history of science. What is true in it is, of course, often emphasised. What is fallacious about it is discussed only by a minority of conscientious scholars. The fallacy in short lies in the tacit equation of global science with science in European history. We have the scope here to discuss it mainly in so far as it has a bearing on the need of understanding the contributions of the Asian countries to the mainstream of science, which are usually ignored or at best desultorily mentioned.

That such an understanding of the history of science is not sufficiently scientific becomes obvious when we consider only one point. Even for the restricted purpose of understanding scientific developments in Europe, it is essential to take note of the contributions of the Asian countries. Let us see why.

19. APPARENT ANOMALY

To begin with, there is something apparently odd about the story as usually told. If the Greek tradition had so much to bequeath to modern science, how was it that among the Greeks and Romans themselves it suffered a creeping paralysis? The question becomes all the more perplexing when we remember that the essential intellectual tools for the making of modern science were worked out by the Greeks long before Galen who died in A. D. 199. As Farrington[58] sums up: "Before the end of the third century B.C. Theophrastus, Strato, Herophilus and Erasistratus, Ctesibius and Archimedes had done their work. In the Lyceum and the Museum the prose-

58. B. Farrington, GS 302.

cution of research had reached a high degree of efficiency. The capacity to organise knowledge logically was great. The range of positive information was impressive, the rate of its acquisition more impressive still. The theory of experiment had been grasped. Applications of science to various ingenious mechanisms were not lacking. It was not then only with Ptolemy and Galen that the ancients stood on the threshold of the modern world. By that late date they had already been loitering on the threshold for four hundred years. They had indeed demonstrated conclusively their inability to cross it."

20. SLAVERY AND THE DECLINE OF GREEK SCIENCE

Why, then, was this inability? We shall quote Farrington again, who has answered the question in his masterly survey of *Greek Science*: "The failure was a social one and the remedy lay in public policies that were beyond the grasp of the age. The ancients rigorously organised the logical aspects of science, lifted them out of the body of technical activity in which they had grown or in which they should have found their application, and set them apart from the world of practice and above it. This mischievous separation of the logic from the practice of science was the result of the universal cleavage of society into freeman and slave. This was not good either for practice or for theory. As Francis Bacon put it, if you make a vestal virgin of science you must not expect her to bear fruit." [59]

When the muscles of the slaves were the only recognised source of power, science became increasingly irrelevant as a means of transforming the conditions of life. It became a relaxation and a pastime for a handful of social parasites. Cut off from the actual process of interrogating nature, the tools and implements for which were left exclusively to the slaves with no social status at all, science ceased to be a knowledge of nature and a power over it. Such was the blind alley into which science was pushed in the Greco-Roman world. Nothing short of a social revolution could rescue it. Between A.D. 400 and 800 the revolution took place, though as the work of the northern barbarians. "Even if in the end," says Engels, "we find almost the same main classes as in the beginning,

59. *Ibid.* 303.

still, the people who constituted these classes had changed. The ancient slavery had disappeared ; gone were also the beggared poor freemen, who had despised work as slavish. Between the Roman *colonus* and the new serf there had been the free Frankish peasant. The 'useless reminiscences and vain strife' of doomed Romanism were dead and buried. The social classes of the ninth century had taken shape not in the bog of a declining civilisation, but in the travail of a new." [60]

21. THE MIDDLE AGES

It is not the place for us to go into the detail of the transition from slavery to feudalism, or, what is more important for the history of modern science, from feudalism to capitalism. But it is of material importance to note the slow operation of historical process that allowed the intellectual movements of the Middle Ages to bring modern science into being in the European cultural area. The most important clue to this is to be sought in the series of technological innovations witnessed by Europe roughly from the ninth century, which gradually transformed the economic basis of society. Quoting an inventory of these (from the IXth century harness of the saddle-horse down to the XVth century printing) prepared by Des Noettes, Farrington observes :

> In another of his writings, a masterpiece of research and of historical analysis, Des Noettes discusses the social consequences of this series of inventions. He is not wrong when he insists that 'by fundamentally transforming the means of production they fundamentally transformed the social organism'. Nor is his conclusion lessened in importance when we understand that one of the transformations of the social organism involved was the disappearance of the last vestige of slavery and the possibility of undertaking immense constructional works with free labour—works of a kind which had normally been performed in antiquity by the forced labour of slaves. This implied an immense improvement in the consciousness of the modern world over the ancient.[61]

22. THE RENAISSANCE

It was with this improved consciousness that Renaissance Europe looked back at Greek science and tried to understand its message, which was lost to the Graeco-Roman world itself.

60. F. Engels, OF 253-54.
61. B. Farrington, GS 306-7.

Graeco-Roman science was good seed, but it could not grow on the stony ground of ancient slave society. The technical revolution of the Middle Ages was necessary to prepare the soil of Western Europe to receive the seed and the technical device of printing was necessary to multiply and broadcast the seed before the ancient wisdom could raise a wholesome crop.[62]

We shall presently return to the question of these technological innovations. Before that, let us try to be clearer about the nature of the inheritance of Greek science by modern Europe. J. D. Bernal warns us against a naive understanding of it :

It would be a mistake, natural enough in the time of the Renaissance but unpardonable now, to assume that all that happened then was the taking up again of classical culture where it left off, or even where it was at its best. What happened was something different and far more important. *The civilisations that took over the classical heritage of science had a hard task to prevent themselves from being stifled by it.....* There was still, however, the vast store of knowledge to be found in books available to any with the desire or skill to read them. The Syrians and Arabs, and after them the medieval schoolmen and the humanists of the Renaissance, had to trace that store step by step back to its Greek originals..... That they managed to absorb and transform it at all was by virtue of their own vigorous cultural developments. The very rediscovery of the works of the Ancients was the effect, far more than the cause, of the spurts of intellectual activity that characterised the beginning of Islamic science in the ninth century, of medieval science in the twelfth, and of Renaissance science in the fifteenth century.

....Late classical culture was limited both socially and geographically. Socially it had become an almost exclusively upper-class preserve and was consequently abstract and literary, for ingrained intellectual snobbery had barred the learned from access to the enormous wealth of practical knowledge that was locked in the traditions of almost illiterate craftsmen. One of the greatest achievements of the new movement which culminated in the Renaissance was to raise the dignity of the crafts and to break down the barriers between them and the learned world.

The geographical range of classical culture had largely been limited to the countries of the Mediterranean and the Near East. Its very completeness formed a barrier to the use of the common stock of techniques and ideas of the other ancient cultures of India and China.

62. *Ibid*, 307-8.

With the breakdown of the Roman Empire the way was open to much wider exchange and influence.[63]

23. INDEBTEDNESS TO THE EAST

We are now nearing the point we have been trying to make. The point is that even for the limited purpose of understanding the history of science in Western Europe, it is not enough to rely exclusively on information of European cultural area. The enormous importance of the contributions of Central and Western Asia to the first foreshadowing of modern science in Europe is now being increasingly realised, though a good deal of more research remains to be done on the subject. But let us leave that point for the present. Let us concentrate instead *only* on the technological innovations of the Middle Ages, without which, as we have just seen, the new enthusiasm for the Greek heritage of Renaissance Europe cannot be understood. How are we to understand these technological innovations? Joseph Needham has boldly answered the question :

> In case after case it can be shown with overwhelming probability that the fundamental discoveries and inventions made in China were transmitted to Europe, for example, magnetic science, equatorial celestial coordinates and the equatorial mounting of observational astronomical instruments, quantitative cartography, the technology of cast iron, essential components of the reciprocrating steam-engine such as the double-acting principle and the standard interconversion of rotary and longitudinal motion, the mechanical clock, the boot stirrup and the efficient equine harnesses, to say nothing of gunpowder and all that followed therefrom. These many diverse discoveries and inventions had earth-shaking effects in Europe, but in China the social order of bureaucratic feudalism was very little disturbed by them.[64]

The importance of the last point mentioned by Needham is surely not to be overlooked. It is connected, as he elsewhere says, with "what I believe is one of the greatest problems in the history of culture and civilisation—namely the great problem of why modern science and technology developed in Europe and not in Asia."[65] For the historian of science in India there is no escape from the problem. One of the ques-

63. J. D. Bernal, SH 266-7. Emphasis added. *Cf.* also p. 243.
64. J. Needham, GT 213.
65. *Ibid*, 154.

tions he is obliged to face is what inhibited the development of modern science in India, in spite of its brilliant early promise.[66]

For the present, what we are trying to understand, however, is a different question. How are we to understand the emergence of modern science in Europe, or, more specifically, the technological stimulants required by it? Here is how Needham sums up the results of his research: "The more you know about Chinese technology in the medieval period, the more you realise that, not only in the case of certain things very wellknown, such as the invention of gunpowder, the invention of paper, printing, and the magnetic compass, but in many other cases, inventions and technological discoveries were made in China which changed the course of Western civilisation, and indeed that of the whole world." [67]

We may be yet far from a thorough and systematic exploration of the other important cultural areas of Asia—notably India and Central and Western Asia. But we have before us the stupendous volumes of Joseph Needham's *Science and Civilisation in China*, and we are expecting from him more volumes of the work.[68] Enough is contained in these to be considered as the most massive verdict on the facile claim that science is an essentially European phenomenon. One man has indeed exploded the myth nourished by generations.

It is mainly on the strength of the results reached in this great work that J.D. Bernal has come out with the following observation on the main point we have been trying to discuss:

66. J.D. Bernal mentions in this connection a possibility which is favoured by some contemporary Indian historians: "In the East, once the earlier stimulus to economic progress failed, the intellectual stimulus also vanished. Both might have revived later, but by the time they showed signs of this, as in India under the Moguls, their development was cut short by the superior commercial and military achievements of early European capitalism." SH 284.
67. Needham, GT 154.
68. "I have just turned 81, and although eleven volumes of the *SCC* series are already out, there are nine more to be finalised and issued before everything planned is completed": Joseph Needham, personal communication dated Dec. 13, 1981.

The technical advances of the Middle Ages were made possible by the exploitation and development of inventions and discoveries which, taken together, were to give Europeans greater powers of controlling and ultimately of understanding the world than they could get from the classical heritage. Significantly, the major inventions....were not themselves developed in feudal Europe. All seem to have come from the East, and most of them ultimately from China...Already enough is known to show that the whole concept of the superiority of Western Christian civilisation is one based on an *arrogant ignorance of the rest of the world.*[69]

24. 'ARROGANT IGNORANCE'

"Arrogant ignorance" is an exasperated expression indeed. But it is hitting the nail on the head and hitting it hard. The old prejudice that science cannot but be an essentially European phenomenon sometimes goes to the extent of flouting obvious facts. Reviewing[70] the papers of a Symposium held in Delhi in November 1950 on *History of Sciences in South Asia*, Needham quotes Filliozat for a rather glaring example of this.

We quote Filliozat over again :

The greatest historians of science have not always escaped from the inconvenience of knowing only one side of the matter. Paul Tannery, so famous for his studies on ancient mathematics, is an example. We know that the trigonometric sine is not mentioned by Greek mathematicians and astronomers, that it was used in India from the Gupta period onwards (third century A.D.), that the *Surya-siddhanta* (fourth or fifth century A. D.) gives a table of sines, that the Arab astronomers knew them from their Indian contacts and passed them on to Europe in the twelfth century A. D., when the work of al-Battani was translated into Latin. The only conclusion possible is that the use of sines was an Indian development and not a Greek one. But Tannery, persuaded that the Indians could not have made any mathematical inventions, preferred to assume that the sine was a Greek idea not adopted by Hipparchus, who gave only a table of chords. For Tannery, the fact that the Indians knew of sines was sufficient proof that they must have heard about them from the Greeks.

If this is the way we are to argue, there was never any science other than Greek science, and the question whether science has any origins other than the Greek 'miracle' is solved in advance. Only a profound study of Indian scientific developments in parallel with those

69. J. D. Bernal, *op. cit.*, 311. Emphasis added.
70. J. Needham in *Nature*, Vol. 168, pp. 64 ff.

which took place elsewhere about the same times can reveal the degree of originality of that science, and hence enable us to understand the role which India played in the history of the growth of man's knowledge of nature.[71]

It is not difficult to mention other examples. Amazed by the discussion of the preparation of alkalies in the *Susruta-samhita*, the eminent chemist and historian of chemistry M. Berthelot suggested that this portion of the *Susruta* could only be a later interpolation inserted into the text after the Indians had contact with European chemists. He had no patience for some elementary chronological considerations which make such a claim palpably absurd and to which P. C. Ray draws our attention.[72]

More examples are perhaps not necessary. But this tendency to flout or ignore facts in defence of the idea of science being a monopoly of the Europeans cannot but lead to the suspicion of racialism, however disguised and even unconscious it may be. In recent years it is passionately argued by some Asian scholars that the whole concept is used for inducing submissiveness among the Asians to the scientifically and technologically superior Western races, *i.e.* for colonial domination and colonial exploitation. "The political purpose behind this was to create a sense of inferiority amongst Asians and use science and technology as an instrument both of intellectual domination as well as exploitation."[73] Significantly, before Europe entered the career of colonial expansion, there was no such zeal to deny or undermine Indian contribution to the mainstream of science. Here is what a Spanish Muslim scholar wrote in A. D. 1068 : "Among the nations, during the course of centuries and throughout the passage of time, India was known as the mine of wisdom and the fountainhead of justice and good government and the Indians were credited with excellent intellects, exalted ideas, universal maxims, rare inven-

71. J. Filliozat CDIM pp. xix-xx. We have quoted the passage as translated by Needham.
72. P.C. Ray in SHSI 369.
73. A. Rahman, Introduction to *Science and Technology in Medieval India : A Bibliography of Source Material in Sanskrit, Arabic and Persian*, p. vi. I have also before me the manuscript of A. Rahman's *Intellectual Colonisation : Science and Technology in East West Relations*, where the same point is more vigorously argued.

tions and wonderful talents. They have studied arithmetic and geometry. They have also acquired copious and abundant knowledge of the movements of the stars, the secrets of the celestial sphere and all other kinds of mathematical sciences. Moreover, of all the peoples they are the most learned in the science of medicine and thoroughly informed about the properties of drugs, the nature of composite elements and peculiarities of the existing things."[74] If, in view of the complexities of Indian history we are being increasingly aware of, such an observation of about a thousand years back appears today to be rather naive, it is also refreshing if for no other reason than the complete absence of racialism—conscious or unconscious.

25. CO-RESPONDENT TO CONSERVATISM

The view of science being a monopoly of Western Europe has other undesirable consequences. It serves the forces of conservatism within the Asian countries,[75] which, in defence of stagnation and *status quo,* prefer to cut off Asian culture from the mainstream of global science. This makes it convenient to project the irrational religious-mystical trends of the past as representing the quintessence of Asian culture. In India at any rate we are painfully aware of where this leads to. In its cruder form, it debauches people's minds by accustoming them to ignore science in favour of obscurantism, which is required for caste hatred and communalism sanctifying malevolence and murder. In its sophisticated form, it inflates our ego and wants us to be convinced that, compared to the inferior ideal of science and rationalism, Indian sages discovered the secret of some mysterious supra-scientific knowledge. S. Radhakrishnan, for example, goes to the extent of regretting the modern fascination for science and rationalism.[76]

74. Abu'l-Qasim Sa'id bin 'Abdur-Rahman bin Muhammad bin Sa'id al-Andalusi's comments on India in *Tabaqat al-Umam* (*Categories of Nations*), A.D. 1068/460 A.H. Quoted by M. Saber Khan, "India in Hispano-Arabic Literature : An Eleventh Century Hispano-Arabic Source for Ancient Indian Sciences and Culture", in *Studies in the Foreign Relations of India* (Professor H. K. Sherwani Felicitation Volume), Hyderabad 1975, p. 359.
75. See S. Nurul Hasan, Introduction to *Ibn Sina : His Life and Contributions* by S. M. Ibrahim, New Delhi 1981.
76. S. Radhakrishnan IVL 127-33.

The Western mind lays great stress on science, logic and humanism. Hindu thinkers as a class hold with great conviction that we possess a power more interior than intellect by which we become aware of the real in its intimate individuality.... Intuitive realisation is the means to salvation.... 'He who knows that supreme *brahman* becomes that *brahman* itself' .... While the dominant feature of Eastern thought is its insistence on creative intuition, the Western systems are generally characterised by a greater adherence to critical intelligence.....From the Socratic insistence on the concept to Russell's mathematical logic, the history of Western thought has been a supreme illustration of the primacy of the logical. Rationalism is deep in our bones, and we feel secure about scientific knowledge and sceptical about religious faith.

Perhaps the only point of any historical significance about this breath-taking generalisation is that only one among the many philosophical trends in India, namely Vedanta, was keen on denying logic and rationalism in order to make room for an abject faith in the scriptures, declaring the scriptures as the repositories of direct spiritual realisation, and all this as sharply contrasted with other philosophical trends strongly defending logic and rationalism.[77] That the philosophical trend glorified by Radhakrishnan received strong support of the Indian law-makers is a pointer not only to its immense prestige among the Indian elites but also to its social function, for obviously enough the law-makers would not boost a philosophy that did not serve their main purpose and the main purpose of the law-makers was the defence of the caste-structure of society.[78] Nevertheless, because of the inflated importance attached to this philosophical trend by scholars like Radhakrishnan and others, considerable confusion is created even among our working scientists, some of whom—with admirable scientific skill in their professional life—are inclined to nourish obscurantist views as their private convictions, perhaps under the delusion that this is the way of seeking sanction of the national heritage. Hence are the well-known cases of "split personality" of our scientists.[79] This, to say the least, is undesirable and self-defeating. However patriotic it may seem, it does create an impediment in the way of the formation of the scientific atti-

77. D. Chattopadhyaya WLWDIP ch. 1.
78. *Ibid.* ch. 5.
79. The point is already mentioned in the *Preface*

tude, without which the present socio-economic set-up can never be radically changed.

26. NOT A MERE CATALOGUE OF SCIENTIFIC ACHIEVEMENTS

But the generalised claim that Indian culture is essentially spiritual is as much a myth as the one with which it is in open collusion, namely that science is something essentially European. We have to scrap both and the right way of doing it is to work for the reconstruction of the origin and development of science and scientific thought in Indian history, as Needham has done in the case of Chinese history. This does not surely mean that we are equipped today to achieve comparable results. What it means is that the work must have priority while we think of the areas of our research. It is important not only for a better understanding of our own cultural heritage but also for correcting the prevailing imbalance in the story of global science. And the work itself, as Needham observed, "remains enthralling".[80]

The work is not easily done. It is necessary for the purpose to seek answers to a considerable number of questions. What did India contribute to the general fund of science and scientific thought specially in the ancient and medieval periods? What were the special areas of these contributions and how are we to account for the importance attached to these? How in different ages did science respond—or was prevented from responding—to the technological experience and the store of empirical knowledge locked up in the craft-lores? How was the literary tradition in science related to the folk tradition, which, as is evident, for example, in the case of medicine, has always been very strong in India? What was the nature of interaction between science and other dimensions of Indian culture, like religion, philosophy and jurisprudence? What was the nature of scientific exchange of India with other countries—with China and Tibet, with Central and Western Asia, with Greece and Rome, and in the still earlier period with Egypt and Mesopotamia? What role did foreign trade and commerce play in this interchange? Above all, how was science related to society in the different stages of Indian history? How

80. J. Needham in *Nature*, Vol. 168 pp. 64ff.

far, in this relation, we are to seek clues to the periods of outbursts in scientific activities alternating with periods of stagnation and decay? Lastly, what were the inhibiting factors that prevented the rise of modern science in India in spite of its early promise and prolonged continuity?[81]

Evidently enough, it is desirable to have a team of historians, scientists, philologists, philosophers and specialists in other branches to tackle such a wide range of questions. There is today some talk in the country of forming such a team. In the meanwhile, something remains to be done. We have to consolidate the results already reached by the earlier generations of scholars.

27. PIONEERING WORK

It is true that compared to the tons of books written on Indian metaphysics, religion and mysticism, there has been a sad neglect of what B. N. Seal[82] called "the work of constructing scientific concepts and methods in the investigation of physical phenomena". But this does not mean that we have to start today from mere scratch. Though in a minority, some of the scholars—both Eastern and Western—went against the stream and took an absorbing interest in the scientific activi-

81. Continuation of the tradition of astronomy specially among the scientists of Kerala may be mentioned here as an example. K. V. Sarma of Hoshiarpur, to whom we are indebted for a good deal of work on the subject, writes (in a personal communication dated 6.1.82 to my friend Sri Ramkrishna Bhattacharya) : "To be sure, there has been steady and rather reverential 'continuity in astronomical science [after Bhaskara II] but streaks of 'progress' through a rationalistic questioning mind had been there, as evidenced by works like *Rasi-gola-sphuta-niti* of Madhava of the 14th century, *Jyotirmimamsa* of Nilakantha (born 1444) and *Ganitayuktayah*, being short rationales of mathematics and astronomy by several astronomers of Kerala. But, even I am at a loss to visualise realistically how they made this progress. The possible explanation could be the nature of Indian tradition of throwing away, *i.e.*, not keeping, the record of the intermediate steps and arguments of derivation, once the resultant formulae have been reached—a tradition in distinct contrast of the Western tradition from early periods."

82. B. N. Seal, PSAH p.iv.

ties in India. The tradition they respresent is not to be slighted. They include the early visiting scientists like I-Tsing (whose medical background is sometimes overshadowed by his image of being a Buddhist monk) and al-Biruni, whose vision of science as an international endeavour led him not only to make Indian works on astronomy available in Arabic translation but also to make Greek works on science available to the Indians translated into Indian language, i.e. Sanskrit.[83]

They include some of the profoundest scholars of the eighteenth, nineteenth and twentieth centuries doing a great deal of pioneering work—searching for the manuscripts, settling their reading, interpreting their science potentials and trying to solve the most difficult chronological questions. The contemporary historian of science in India cannot but depend on their work. But their contributions remain buried often in the brittle pages of rare journals, often in books gone long out of print, and thus becoming increasingly inaccessible to us.

It remains for us to add only one point. Admirable though the contributions of the pioneers are, indispensable though these may be for the contemporary historians of science in India, the presentation of these in the form of a convenient handbook can in no way be claimed as an adequate account

83. In the Introduction to *Ghuraat al-Zigat or Karana Tilaka* (A Handbook of Astronomy by Bijayanand [sic] of Benaras), Translated from Original into Arabic...by...al-Biruni [prepared for publication by N. A. Baloch], Sind (Pakistan), Institute of Sindhology, 1973, are mentiond the following books translated into Sanskrit by al-Biruni :
(a) *Elements* of Euclid (No. 30).
(b) *Almagest* of Ptolemy (No. 31).
(c) Book on Astrobale by al-Biruni (No. 32).
(d) Key to the Science of Astronomy by al-Biruni (No. 8).
It seems however that these translations were not preserved, because from the *Rekhaganitam* of Jagannatha we learn that under the direction of Jayasimha II (of Jaipur, ruled A. D. 1699-1743) Ptolemy's *Almagest* (*Majisti*) and the *Elements* of Euclid (from the Arabic versions of al-Tusi) were translated again into Sanskrit : see S. N. Sen, *A Bibliography of Sanskrit Works on Astronomy and Mathematics*, New Delhi 1966, pp. 89-99. Incidentally, as a reminder to the norm of internationalism in science, it may be mentioned here that Jagannatha's *Siddhantasamraj* repeatedly refers to the work of Ulugh Beg of Samarkand.

of science in Indian history. As is perhaps evident from some of the questions just mentioned, science in Indian history is an enormously complicated subject and is surely not to be confused with some kind of a catalogue of the prominent achievements of Indian scientists. We have, for example, the model of such a catalogue as prepared by Th. Stcherbatsky in 1923. In spite of perhaps what is inevitable, namely that some of his observations are in need of correction in the light of later researches, the usefulness of such a catalogue when it was prepared is not to be undermined. It was then some kind of a novelty and it was in response to a necessity then keenly felt. We can judge this from what Stcherbatsky said only a few years before (1916) :

> The Indian thought on the whole still remained enveloped in the mist of oriental fantasy and the orderly forms of its consistent logical theories were hidden from the keen sight of the historians of philosophy owing first to the inadequacy of the material available to them and second to the lack of any systematic methods for its scientific study. Besides this stage of scientific knowledge, there could be discerned, in the wider circles of reading public, a morbid interest in Indian philosophy caused by the hazy state of our knowledge of the subject and the various fables of supernatural powers rampant therein.[84]

It was in such a situation that Stcherbatsky wanted his readers to meet the logicians and the atomists, the astronomers and the mathematicians, the physicians and the chemists, the technicians and the engineers of ancient India. A mere list of them and of some of their achievements could be and were indeed of much significance for the earlier stage of historical research, though the fact is that many earlier conclusions have been rejected and corrected.

We have no doubt outgrown this stage. This is not merely because the different areas of scientific activities in India are more intensively explored and still being explored, though only by a minority of scholars. It is more particularly because of the profound change in the scientific historiography of science that has in the meanwhile taken place. But basically the same model of catalogue-making without any reference to the social and economic factors sometimes persists, as is evidenced by

84. Th. Stcherbatsky, Introtuction to the Russian translation of Dharmakirti's *Santanatara-siddhi*. Petrograd 1916. See *Papers of Stcherbatsky*, Calcutta 1969, 73.

Binoy Kumar Sarkar's *Hindu Achievements in Exact Sciences* (1918) and the much more enlarged version of practically the same model in *A Brief History of Science in India* (1971) edited by D. M. Bose, S. N. Sen and B. V. Subbarayappa.

Its other limitations apart, the model of catalogue-making remains exposed to a number of risks. The most serious of these seems to be that it may encourage the tendency to look at science as some kind of an autonomous discipline without being basically influenced by society. That is not helpful for understanding science either in Europe or in Asia. Let us end by quoting Joseph Needham.

28. SCIENCE AND SOCIETY : J. NEEDHAM

In recent decades much interest has been aroused in the history of science and technology in the great non-European civilisations, specially China and India, interest, that is, on the part of scientists, engineers, philosophers, and orientalists, but not, on the whole, among historians. Why, one may ask, has the history of Chinese and Indian science been unpopular among them? Lack of the necessary linguistic and cultural tools for approaching the original sources has naturally been an inhibition, and of course if one is primarily attracted by +18th and +19th century science European developments will monopolise one's interest. But I believe there is a deeper reason.

The study of great civilisations in which *modern* science and technology did not spontaneously develop obviously tends to raise the causal problem of how modern science did come into being at the European end of the Old World, and it does so in acute form. Indeed, the more brilliant the achievements of the ancient and medieval Asian civilisations turn out to have been the more discomforting the problem becomes. During the past thirty years historians of science in Western countries have tended to reject the sociological theories of the origin of modern science which had a considerable innings earlier in this century. The forms in which such hypotheses had then been presented were doubtless relatively crude, but that was surely no reason why they should not have been refined. Perhaps also the hypotheses themselves were felt to be too unsettling for a period during which the history of science was establishing itself as a factual academic discipline....

"The study of other civilsations therefore places traditional historical thought in a serious intellectual difficulty. For the most obvious and necessary kind of explanation which it demands is one which would demonstrate the fundamental differences in social and economic structure and mutability between Europe on the one hand and the great Asian civilisations on the other, differences which would account not only for the development of modern science in Europe alone, but also of capital-

ism in Europe alone, together with its typical accompaniments of protestantism, nationalism, etc., not paralleled in any other part of the globe.....

But if you reject the validity or even the relevance of sociological accounts of the 'scientific revolution' of the late Renaissance, which brought modern science into being, if you renounce them as too revolutionary for that revolution, and if at the same time you wish to explain why Europeans were able to do what Chinese and Indians were not, then you are driven back upon an inescapable dilemma. One of its horns is called pure chance, the other is racialism however disguised. To attribute the origin of modern science entirely to chance is to declare the bankruptcy of history as a form of enlightenment of the human mind. To dwell upon geography and harp upon climate as chance factors will not save the situation, for it brings you straight into the question of city-states, maritime commerce, agriculture and the like, concrete factors with which autonomism declines to have anything to do. The 'Greek miracle', like the scientific revolution itself, is then doomed to remain miraculous. But what is the alternative to chance? Only the doctrine that one particular group of peoples, in this case the European 'race', possessed some intrinsic superiority to all other groups of peoples. Against the scientific study of human races, physical anthropology, comparative haematology, and the like, there can of course be no objection, but the doctrine of European superiority is racialism in the political sense and has nothing in common with science. For the European autonomist, I fear, 'we are the people, and wisdom was born with us'. However, since racialism (at least in its explicit forms) is neither intellectually respectable nor internationally acceptable, the autonomists are in a quandary which may be expected to become more obvious as time goes on. I confidently anticipate therefore a great revival of interest in the relations of science and society during the crucial European centuries, as well as a study ever more intense of the social structures of all the civilisations, and the delineation of how they differed in glory, one from another.

In sum, I believe that the analysable differences in social and economic pattern between China and Western Europe will in the end illuminate, as far as anything can ever throw light on it, both the earlier predominance of Chinese science and technology and also the later rise of modern science in Europe alone.[85]

29. CONCLUDING REMARKS

We have quoted Needham at some length, as we have quoted Bernal at the very beginning for we have in these the main

guidelines for our own work. Not that we have in our humble team anybody of Needham or Bernal's stature nor do we delude ourselves with the idea that we are going to achieve anything even remotely comparable to what they have done. Nevertheless, we shall consider our attempt amply rewarded if it is considered as a step—howsoever faltering and tentative it may be—towards a history of science in India and if the errors or inadequacies in it may negatively stimulate more competent scholars to work on a better study of the subject.